DIVISION OF THE HUMANITIES AND SOCIAL SCIENCES

CALIFORNIA INSTITUTE OF TECHNOLOGY

PASADENA, CALIFORNIA 91125

A DYNAMIC THEORY OF COMPETITION

Burton H. Klein

SOCIAL SCIENCE WORKING PAPER 59

October 1974

A DYNAMIC THEORY OF COMPETITION

Burton H. Klein

I. COMPETITION AND PROGRESS

What is the relationship between competition and progress? It can be assumed that as of any given moment technologies provide different potentials for satisfying human desires. For example, it can be assumed that if Henry Ford had decided to enter, say, the pin making rather than the automobile business, he would have found in the former a lower potential: even if the elasticity of demand for pins were very high, there simply may have been no real opportunity to bring about a significant reduction in the cost. In other words, the potential as far as pin making was concerned might have been more or less completely exhausted. And if we assume an economy of pin mills, then obviously there could be little or no competition in ideas and no real progress.

Another way of describing a world in which the technological potentials have been entirely exhausted is by observing that in such a world competition can produce no better results than in a zero-sum game. To be sure, there can be gains from trade. But after these gains have been exhausted no one can be made better off without making someone else worse off.

By way of contrast, consider the remarkable degree of progress which was made in heart operations during the past twenty years. How was this progress brought about? Teams of surgeons assumed that this was a field in which there was a substantial potential for discovering better operating techniques. In other words, it was a field in which surgeons recognized their ideas were but partial truths. And there was very intense rivalry between teams of surgeons to find better

approximations to the truth -- rivalry which generated a wide diversity of ideas. And it was this diversity of ideas which, in turn, permitted remarkably smooth progress in reducing the fatalities associated with particular types of heart operations.

Here we have a type of competition which quite clearly produced better results than in a zero-sum game. The more imaginative surgeons quickly developed reputations which allowed them to build up their practices very rapidly. It is true they took business away from the less imaginative doctors. But the less imaginative doctors were able to borrow ideas which simply would not otherwise have been available to them. Moreover, no single surgical team had a monopoly on good ideas. And since the improvement in performance depended on a number of discoveries (with earlier discoveries providing hints for later discoverers), there were, so to speak, innumerable opportunities to win a "Nobel Prize." So here quite clearly was a form of competition which produced better results than in a zero-sum game, whereby almost everybody was made better off -- all except the undertaker whose payments were delayed. Indeed, it can be described as a situation in which it paid to cooperate by competing.

Is this, then, a new form of competition? Not at all. Long before the scientific movement began in agriculture, farmers were cooperating by competing to grow the biggest potatoes and the fattest hogs. In fact, one of the main reasons the early agricultural experimental stations were so successful is that they were dealing with the most progressive sector of the United States economy in which there was a genuine demand for new ideas.

More generally speaking, it can be argued that the fundamental reason seven-eighths of the growth of this country took place as a pure productivity increase (GNP divided by the weighted inputs)[1] is that in the exploitation of new technological potentials, competition in this country produced better results than could be achieved in a zero-sum game. Moreover, it also can be argued it was no accident that as of the turn of the century this country became the technological leader of the world in the introduction of new products into world markets. According to Kuznets' calculations, shortly after the Civil War, when the rapid industrialization of the United States economy began, productivity in this country was quite as high as that of any other country in the world.[2] It may be assumed the fundamental reason for this is that although we were still importing most of our industrial technology from Britain, American agriculture already was highly progressive. So it is quite clear that continued improvements in productivity in this country would require us to become a technological leader in discovering new technological gold mines, and wringing out their potential.

Thus, while the growth and trade paradoxes are often regarded as quite different paradoxes -- the one a paradox for growth theory, the other a paradox for trade theory -- the fact of the matter is that they are one and the same paradox. The growth paradox results from the fact that classical theory cannot explain why a very large fraction of this country's growth took place as a pure productivity increase.[3] On the other hand, the trade paradox, as it has been restated by Vernon, consists of explaining why we exported newer technologies in exchange for older technology.[4] However, as was already indicated, if we had not become more or less self-sufficient in the generation of new technological ideas, it is quite unlikely the gains in productivity would have been as rapid as they were. So it can be assumed that our relative advantage as a generator of new ideas was intimately related to the economic development of the United States. In fact, it was not until after World War II that we recognized ourselves to be the technological leader of the world.

To be sure, it can be argued that from a cost-effectiveness

point of view this country would have been better off if the cities of Birmingham, Nottingham and Manchester (which were inhabited almost entirely by people from Scotland and Dissenters from the Church of England as of the beginning of the Industrial Revolution -- Adam Smith among them) had continued to have a technological revolution every twenty years. Not only are R&D costs much higher than licensing costs, but very substantial learning costs are involved in debugging new production processes. However, the British Industrial Revolution was mainly centered upon exploiting the potential of a single major discovery -- namely, the steam engine. And when the potential was exhausted, this country had no alternative but to become self-sufficient in the generation of technological ideas if it wanted to enjoy a continued increase in productivity along with the discovery of new consumer goods which would enable people to enjoy a wider diversity of experiences (e.g., the radio, television, movies, etc.).

Since it is cheaper to be a borrower of ideas than a generator of ideas, it is not very surprising that on the whole the other major economies of the world were able to increase productivity somewhat more rapidly than the United States. This is indicated by Kuznets' international comparisons of labor productivity:

Annual Increases in Productivity, 1900-1960[5]

United States	1.5
United Kingdom	1.2
Sweden	2.5
Japan	2.7
Germany	1.3
France	1.4

It is true that for the period as a whole, the performance of neither the United Kingdom, Germany nor France was appreciably better than that of the United States. But after World War II there was a very remarkable improvement in the performance of both Germany and France. Thus, according to Denison's estimates, during the period 1950-1962, total factor productivity in Germany increased at about three times the British rate, and in France at about twice the British rate.[6] So given the fact this country was the technological leader during this period, the increases in productivity in other countries can be looked upon mainly as a process of catching up with our potential, with Japan and Sweden displaying the best capability as borrowers and Britain the poorest.

What, then, enabled this country to do as good a job as it did in taking advantage of technological potentials? According to the conventional wisdom, our advantage in education played a major role in explaining both the growth and trade paradoxes. Thus, according to Denison's estimates, something like half of the residual is to be attributed to investment in human capital, as measured by increases in the number of years of schooling.[7] Vernon and Gruber have argued that in trading newer for older technologies, we were trading "brain for brawn."[8]

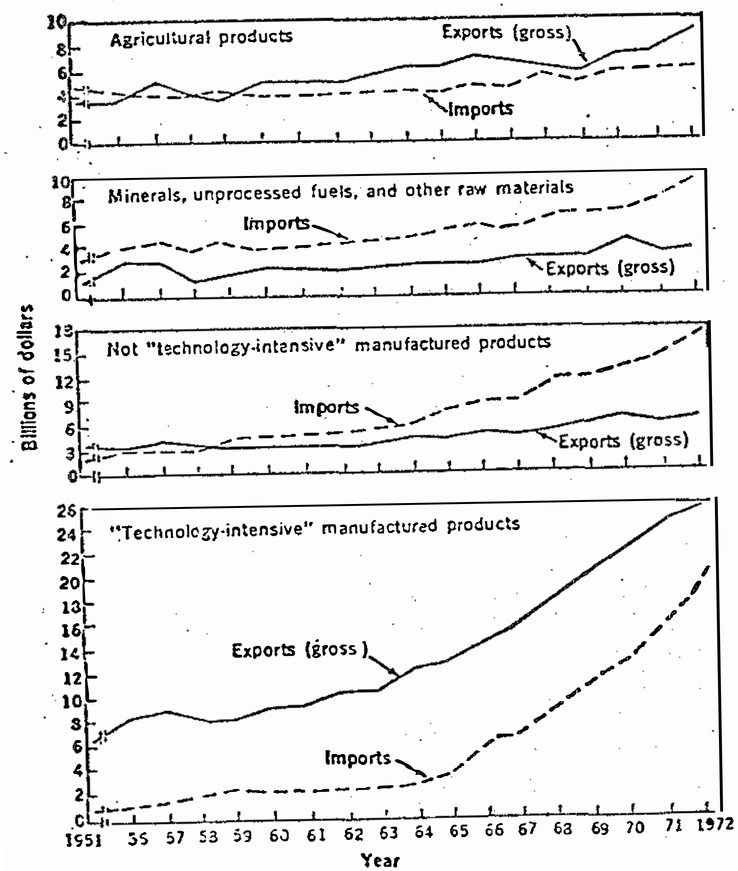
There are, however, two reasons for being skeptical about the assumption that it was the advantage in education which was primarily responsible for this country's splendid economic performance. It is by no means clear whether investment in education as measured by the number of years of formal training is to be regarded as a cause or the result of productivity increases. And, while we seem to hold the same advantage in education, our economic performance no longer is so splendid. As already was indicated, our productivity revolution began in agriculture; though it hardly can be argued this was because farmers were the most educated people in the country. Furthermore, a number of famous American inventors, Thomas Edison among them, never had any formal schooling. So how can we be sure whether education was a cause or an effect: an investment good which caused increases in productivity or a consumption good made possible by increases in productivity?

The second reason for being skeptical about the educational hypothesis is the recent economic performance of the United States. As Chart 1 shows, whereas this country once held a near monopolistic position in introducing new products into world markets, it is apparent today we no longer do: the United States is now importing about half as much of the "technology intensive" commodities it is exporting. Moreover, as Chart 1 also shows, American firms are much less competitive than they were with respect to the older technologies. Indeed, the only area in which we still seem to have a clear advantage over the rest of the world is in agriculture.

Since a country's most competitive goods enter international trade, it can be assumed that when a country's trade position worsens, productivity increases will decline relative to other countries. And just as Britain entered her Victorian Age with relatively poor performance in both productivity and trade, so is the case in the United States. As Chart 2 shows, in manufacturing, the rate of productivity increase has declined so much relative to other countries that we are now falling behind Britain.

How, then, is the relatively poor performance of the United States economy to be explained? If we dismiss the education argument, there would appear to be two plausible hypotheses: (a) that it reflects a vanishing of technological opportunities; and (b) that it reflects a decline in competition. Economists have, of course, long recognized that advances in technology tend to be bunched in time -- with advances in one field leading to advances in another. So acceptance of the first hypothesis would place main emphasis on the fact that the post-World War II industrial revolutions seem to be dying out.

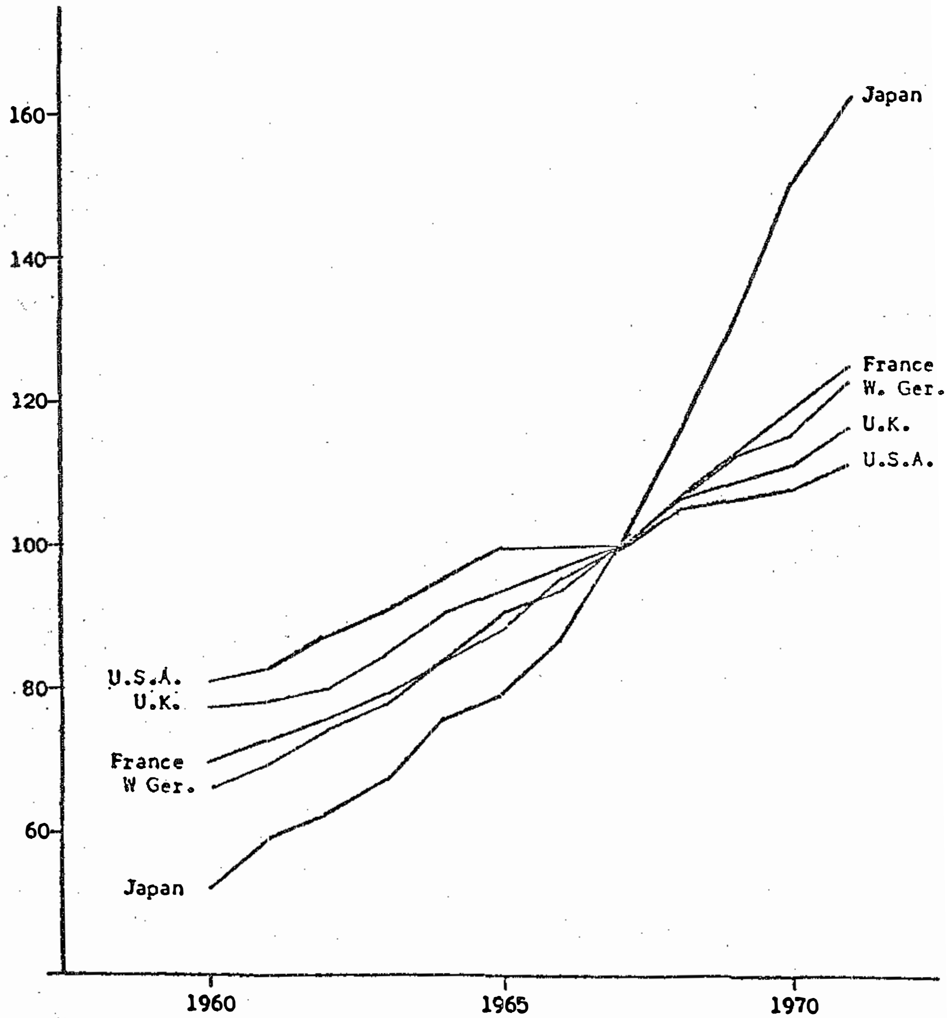
CHART 1



Graphs taken from Science, 179 (March 2, 1973), Michael Boretsky.

CHART 2

INDEXES OF OUTPUT PER MAN-HOUR IN MANUFACTURING (1967=100)



Data taken from "Unit Labor Costs in Eleven Countries," Arthur Neef, August 1971, Monthly Labor Review, U. S. Department of Labor, Bureau of Labor Statistics.

But a decline in the potential can lead to a decline in competition in ideas -- and a decline in competition in ideas to a poorer ability of an economy to open up new potentials. Thus, the second hypothesis does not necessarily assume the potential of a technology will always remain the same. What it does assume is that progress is not automatic -- a decline in competition in one period can bring about a poorer ability to promote progress in the next. For example, the dying out of the technological revolutions in Britain may have a good deal to do with the fact that they were centered on exploiting the potential of a single invention: the steam engine. But the British economy may not have recovered to this very day from the Great Depression of 1880 in the sense that never was there a recovery of competition in Britain. So, if economists do not try to understand the relationship between competition and progress, we may find what has happened in Britain will happen here also.

II. THE NEED FOR A DYNAMIC THEORY

The principal difference between the two hypotheses suggested previously is that, whereas the first assumes an automatic theory of progress, the second does not. An automatic progress theory is one which assumes the knowledge for productivity gains is brought about outside of the economic system -- and more or less routinely is translated into producing a given level of output with fewer inputs. For example, many economists not only assume that science is a pail of all-purpose knowledge, which can be turned into useful technology at will, but also that in competition there is a more or less automatic mechanism for taking advantage of improvements in knowledge. If a way exists for improving productivity, competition will exploit it; if it does not, competition is of no avail. And if one takes this point of view,

then the trade-off depicted in the Phillips Curve (between the degree of unemployment and the rate of inflation) must be taken as a given. To be sure, larger gains in productivity would be preferred to smaller gains -- larger gains would insure a greater opportunity to pay for increases in real wages without causing inflationary pressures. However, since advances in knowledge are exogenous to the economic system, there simply is no way to avoid choosing between the degree of unemployment and the rate of inflation.

Moreover, if policymakers choose more inflation as the lesser of two evils, then it must be assumed that this choice will more or less inevitably lead to a greater and greater degree of economic controls. True, controls do not deal with the basic problem, which is increasing the rate of productivity gain. However, if it is assumed that the rate of productivity advance is determined by exogenous factors, then the only real alternative to a 7 or 8 percent unemployment rate is economic regulation. Moreover, when regulation does not work as intended, it is typically assumed that the problem was not with the medicine, but rather with the dose. And for this reason it is no accident that other than the Communist countries, the British economy is one of the most controlled in the world.

According to the second hypothesis, the trade-off depicted by the Phillips Curve need not be taken as a given. As long as there are unexploited technological potentials in an economy -- as long as the economy is not an economy of pin mills -- the rate of progress can be affected by the degree of competition. The degree of competition is defined as the degree of interaction between competitors in the risk they impose on each other. Let us assume we are observing an industry in which competitors face large risks as measured in terms of the markets won or lost as a result of the introduction of new products. In such an industry, if a firm wanted to survive, it always would have to be balancing two risks: a technological risk and a competitive risk. At any given moment, firms in such an industry can be confronted by serious dilemmas, which involve having to choose between two equally unfavorable alternatives: whether acting upon a technological risk will result in a commercially successful product or whether it will lose a market as a result of a competitor's introduction of new products.

So not only is there (1) a high degree of interaction in the markets which can be gained or lost as a result of the introduction of new products, but (2) because competitors never can make probabilistic calculations of the risks they face when acting upon or refusing to act upon a particular technological risk, they can be said to be dealing with risks under conditions of strong uncertainties. Unfortunately, in this case they cannot insure themselves against such risk by buying insurance from insurance companies. So what must a firm do if it wants to survive? It must cooperate with its competitors by hiring some imaginative people to do to its competitors what its competitors can do to it! Indeed, as already was pointed out, it is only as a result of such cooperation that competition can produce better results than can be achieved in a zero-sum game.

However, business firms not only can cooperate by imposing large risks on each other, but they can cooperate by failing to interact with each other, and by imposing risks upon the public at large. Consider, for example, the following situation as described by Adam Smith:

> People in the same trade seldom meet together, even for merriment or diversion, but the conversation ends in a conspiracy against the public or in some contrivance to raise prices.[9]

Such a situation can be described as one in which there is a zero degree of interaction between competitors in the risk they impose upon each other -- as one which can generate no better results than can be achieved in a zero-sum game. Now, no competition might exist

either because (1) the technological potential of the industry in question already has been more or less completely exhausted, or (2) rather than imposing risks upon each other, firms in an industry prefer to impose risks on the public at large. However, unless it is assumed that all the technological potentials have been completely exploited, then there is a trade-off other than that depicted by the Phillips Curve. Assuming that the inability to cope with inflation inevitably will mean more regulation, it is the trade-off between the regulation of monopoly and the promotion of competition to better internalize risks. When competitors cooperate by imposing risks upon each other, the process can be described as a risk internalization process in the sense that if a competitor decides to act upon technological risk in order to avoid a competitive risk, then he internalizes a risk for society as a whole by making the future rate of progress more predictable. And, as an alternative to direct regulation, the government can undertake measures to help insure risks are more fully internalized. For example, if in a highly concentrated industry wherein they do not impose genuine risks upon each other, firms would face the risk of a dissolution suit brought about by the government. And labor unions might be made to feel more risk if by imposing serious constraints on the ability of firms to bring about productivity advances, they too were made to feel the risk of dissolution. Moreover, there are a variety of ways the tax structure might be revised to encourage a greater degree of risk-taking. For example, by favoring smaller firms, a more steeply graduated corporation income tax might encourage more risk-taking. Thus, once it is acknowledged competition and productivity gains are related, then we can consider the trade-off between those measures designed to regulate monopoly and promote risk internalization.

However, there is an even more fundamental trade-off than in the type of regulation which is involved. There is the trade-off between micro- and macrostability. As used in this paper, the term 100 percent microstability means completely predictable microbehavior. For example, if the teams of surgeons engaged in heart operations were completely predictable inasmuch as they never generated nor borrowed any new ideas, they could be described as enjoying complete microstability. On the other hand, if, as a result of making new discoveries and rapidly adopting the more successful ones, smooth progress was made with respect to particular types of heart operations, then these surgeons would be enjoying macrostability: the more rapid the rate of increase, the greater the degree of macrostability. Because "macrostability" is a key concept in dynamic theory, it will be discussed in greater detail. For the moment however, the main point to be emphasized concerns the trade-off between micro- and macrostability: it is impossible for a society to simultaneously conserve its micro- and macrostability. Entirely predictable societies, it should be apparent, can enjoy 100 percent microstability while possessing a zero degree of macrostability. Conversely, the more rapid the rate of progress, the greater the requirement on unpredictable microbehavior.

One way to think about the difference between micro- and macrostability is to think about the difference between the United States and British economy as of, say, twenty years ago. It is no accident the Phillips Curve was discovered first in Britain. Unlike this country, since the turn of the century Britain has had a chronic inflation problem. Moreover, anyone familiar with dynamic economic theory could predict that Britain would have a relatively poor ability to bring about productivity gains. It is apparent from Marshall's description of the British economy that Britain is a country which features micro- and not macrostability. As the most outstanding observer of British reality since Adam Smith, Marshall described British society in terms of a semi-closed system paradigm: a paradigm which emerged from

Darwinian biology and consequently assumes all evolution takes place in terms of a given environment.[10] Such evolution takes the form of an increasing degree of specialization -- as an inbreeding process -- and is highly predictable. As Marshall himself made the point in the frontispiece to his book: Natura non facit saltum (nature does not change by leaps). And a nation which features a high degree of microstability simply cannot feature a high degree of macrostability.

Conversely, in the past the United States was a country which featured macrostability rather than microstability. This is apparent from the fact that as the technological leader of the world for about half a century we were the most predictably unpredictable country in the world. It could not be predicted just what particular advance would come out of the United States next, but the United States could be counted upon to lead in introducing new products. And it was this high degree of unpredictable microbehavior which, in turn, made the rate of progress highly predictable.

As will be shown, the real significance of competition which can produce better results than can be achieved in a zero-sum game is that it is the degree of interaction of competitors which determines the macrostability of a country. And if we assume such a relationship does exist, then the need to introduce dynamic theory into economics is quite apparent: it is to make economists more aware of important trade-offs not disclosed by static theory.

III. THE ELEMENTS OF DYNAMIC THEORY

Dynamic theory has three principal elements. First, it has a dynamic concept of stability: the ability to make smooth progress in overcoming dilemmas. Second, it has a dynamic concept of competition: interactions between competitors which can generate better results than in a zero-sum game and thereby promote macrostability. Third, it has a central and unifying concept: the concept of "openness." It is a central element, because it enables us to explain how people can use hints obtained as a result of the diversity of their experiences to generate new ideas. Without such a capability people would become prisoners of their environments. It is the unifying element, because the concept of openness enables us to relate microbehavior to macroperformance. Assume that the rate of progress in an industry declines by a factor of two. Then we should be able to predict the change in the internal characteristics of firms associated with that loss of macrostability.

The concept of "openness" is not new. Known as the concept of an "open system," it has been responsible for the post-Darwinian revolution in biology. However, while writing a book on economic dynamics[11] I was fortunate to discover the key ideas contained in modern biology were anticipated in the writings about democracy by Thomas Jefferson and Lazare Carnot. Lazare Carnot is mainly known for having pioneered (with his son, Sadi Carnot) the science of thermodynamics. But in his earlier writings, he, like Jefferson, developed a theory of democracy around the concept now known as an "open system." This was a fortunate discovery inasmuch as it enabled me to clearly understand the relevance of the concept as far as economics is concerned.

After describing these three elements of dynamic theory I will return in the final section of this paper to the application of dynamic theory to policy issues.

III-1. The Concept of Macrostability

In Keynesian economics the generally accepted definition of macrostability is "prosperity without inflation." However, there is no explicit recognition for the need for productivity gains. In fact, Keynes was quite explicit in leaving this out of his theory:

> We take as givens the existing skill and quantity of available labor, the existing quality and quantity of available equipment, the existing technique, the degree of competition, and habits of the consumer.[12]

It is somewhat surprising Keynes assumed a Ricardian world, because no one was more critical of classical equilibrium theory.[13] Moreover, the General Theory can be regarded as a first step towards a dynamic theory inasmuch as it introduced the cybernetics approach into economics: on the basis of short-term predictions of the interaction between public and private spending decisions, steersmen at the President's Council of Economic Advisors or the British Treasury provide advice and monetary and fiscal policies which hopefully will keep the nation's economic ship of state on a full employment course. I describe this type of theory as economic cybernetics, because it is much like the cybernetic theory employed in sailing a ship: the captain makes short-term predictions of the interaction between the waves and the ship, and on the basis of such short-term predictions makes corrections necessary for keeping on a predetermined course. This is not dynamics in the sense to be defined as follows; but neither is it static theory. If the captain were to behave as a static system, he would set his rudder in New York on the basis of his initial predictions, and hope he would arrive in Le Havre.

But, while the Keynesian revolution was a revolution only half completed because it did not change microtheory, Keynes himself certainly cannot be blamed. His mission was to provide a rationale for dealing with serious depressions. And for that purpose a reform of microtheory was not required. Moreover, as far as Britain is concerned, he may have done no serious injustice to the facts by ignoring competition.

However, since the United States is not Great Britain, I propose that gains in total factor productivity (GNP divided by the weighted inputs) should be regarded as a measure of the macrostability of an economy. Though many economists regard all firms as alike (and microcosms of the GNP accounts), it is not necessary to assume that the rate of increase in all industries is the same. In fact, I will later show why it cannot be the same. So let us assume that increases in total factor productivity can be regarded as the weighted average of all industries: with each industry weighted, say, in terms of the proportion of the labor force it employs.

Now, why is this a dynamic measure of stability? For one thing, it involves the element of "time." For another, in all dynamic processes the path is crucial because earlier "experiments" provide clues for later discoveries: the more hints from previous discoveries, the more new discoveries which can be made as a result of ideological mutations. But in terms of my definition the essential element of a dynamic process is that it must involve types of microbehavior which, when viewed as single events, are quite unpredictable. In other words, dynamic theory is concerned with making prediction on a macroscropic, rather than a microscopic basis.

Particular gains in productivity tend to be quite unpredictable, because nature was constructed in such a way that man is required to employ his imagination when dealing with dilemmas! Let us assume that a firm would like to develop a machine which is 20 percent more efficient than the current menu (though it feels there is a real risk involved, there is also a risk a competitor might develop such a machine). The members of the firm know the second law of thermodynamics imposes practical limits on the efficiency of machines, given the best available fuels and materials. And furthermore, they know if someone can find a way to increase the temperature difference by discovering more suitable materials, improved fuels or engineering tricks to make the machine better approximate an ideal reversible machine, they will have a superior product. Knowing this, they find themselves on the horns of a dilemma (which means being confronted by two equally unfavorable alternatives): (1) there is a monetary risk involved in discovering a

way to build a machine they do not know how to build; (2) there is the risk of having a competitor steal the show.

What must happen if the firm in question is to resolve this dilemma in its favor? The firm must overcome a discontinuity, which in my terms means it must acknowledge its previous ideas were only partial truths; in other words, it must add to its stock of knowledge. Dynamic competition is a competition to obtain new knowledge. Moreover, the behavior involved is dynamic not only inasmuch as it involves a change in initial conditions, but also because it involves a quite unpredictable change in initial conditions -- a change which simply could not be programmed on a computer.

Knight made the general point very well in the preface to his Risk, Uncertainty and Profit (written in 1915), when he observed:

> I must regard it as one of the major errors in the classical tradition that it failed, and still largely fails to make a sharp and correct theoretical distinction between the working of a system under given conditions, including movement towards equilibrium, and changes in the given conditions or content of the system itself.[14]

And he himself helped make the distinction clear when he pointed out in his later writings that:

> It is practically impossible to imagine any investment in the real world which is not in some degree rationally experimental, in the sense of being reasonably expected to lead to knowledge having some enduring economic significance. That is, all investment consists, in part, in investment in new knowledge.[15]

The distinction between the workings of an economic system under given conditions and changes in initial conditions is that, whereas the former involves highly predictable problem solving activities, the latter involves quite unpredictable additions to the stock of knowledge. The distinction, in other words, is the distinction between a system working under conditions of weak uncertainties and a system working under conditions of strong uncertainties. And the degree of uncertainty obviously will depend on the extent initial conditions are changed.

Improving the efficiency of a machine by only 2 percent will involve overcoming only a minor discontinuity, and, therefore, will not require the degree of unpredictable behavior involved in bringing about a 20 percent advance. In other words, there is a trade-off between the degree of advance sought and the degree of uncertainty involved.

It should be pointed out technological dilemmas arise not only because of practical limits imposed by the second law of thermodynamics, but also because although engineers might like to scale a machine now being used in another application to obtain better efficiency (e.g., scale turbine engines so they can be used in automobiles), there are constants in the laws of nature and in materials which prevent scaling at will. In fact, Galileo is usually credited with making this discovery, because when in his Two Sciences he asked how big a bone would be required to build a dog twice as high, he found it simply could not be done without the invention of a stronger bone. And for this reason, it is often said Galileo discovered engineers are needed to invent new kinds of bones! It should be apparent, therefore, no one really can deny the existence of dilemmas without denying the laws of nature as they have been known since the time of Galileo.

Moreover, surprises do not occur only in research and development activities. There are substantial learning costs involved in taking the bugs out of new production processes and in retraining workers. In fact, one of the main arguments made by people in the automobile industry for concentrating production so an entire range of, say, intermediate automobiles can be produced in one plant is that such concentration permits the concentration of learning.

Wringing out the potential of a new technology ordinarily involves finding ways to overcome limits imposed by both the second law of thermodynamics and scaling. And because the opportunities eventually become exhausted -- or are assumed to be exhausted -- improvements generally take the form of an S-shaped curve (see Chart 3). The overall shape of the curve is very smooth, almost as if it were preordained. However, the smoothness can be explained only as a result of quite unpredictable types of behavior involved in overcoming discontinuities. As is indicated, the typical picture is a series of discontinuous steps, with the discontinuities becoming smaller as the peak of the curve is reached.

It should be apparent, however, that whereas the shape of these curves tends to be the same, the time required to reach the plateaus might be ten years -- or it might be fifty years. And if my hypothesis is correct, it is the degree of competition which determines how rapidly the potential is exploited.

What happens when the potential of a particular technology is exhausted? In some fields, we can observe only one S-shaped curve. But in others, for example, commercial aircraft, a discovery like the jet engine resulted in a new S-shaped curve at just about the same time the potential of piston-driven aircraft was being reached. So, here there was evidently a case with a greater potential (see Chart 4). Or in the field of chemistry or computers, we can observe overlapping S-shaped curves (see Chart 5). And it may be assumed these involved an even greater potential.

To conclude this part of the discussion: the degree of macrostability an economy can achieve depends on its ability to engage in unpredictable microbehavior in exploiting new technological potentials. And the trade-off between microstability and macrostability arises from the fact that the greater the degree of macrostability which is required, the stronger are the uncertainties involved, and the stronger the uncertainties, the greater the requirement on unpredictable microbehavior. However, it should not be assumed that dealing with strong uncertainties constitutes "abnormal" behavior, and dealing with weak

CHART 3

Evolution of a Technology

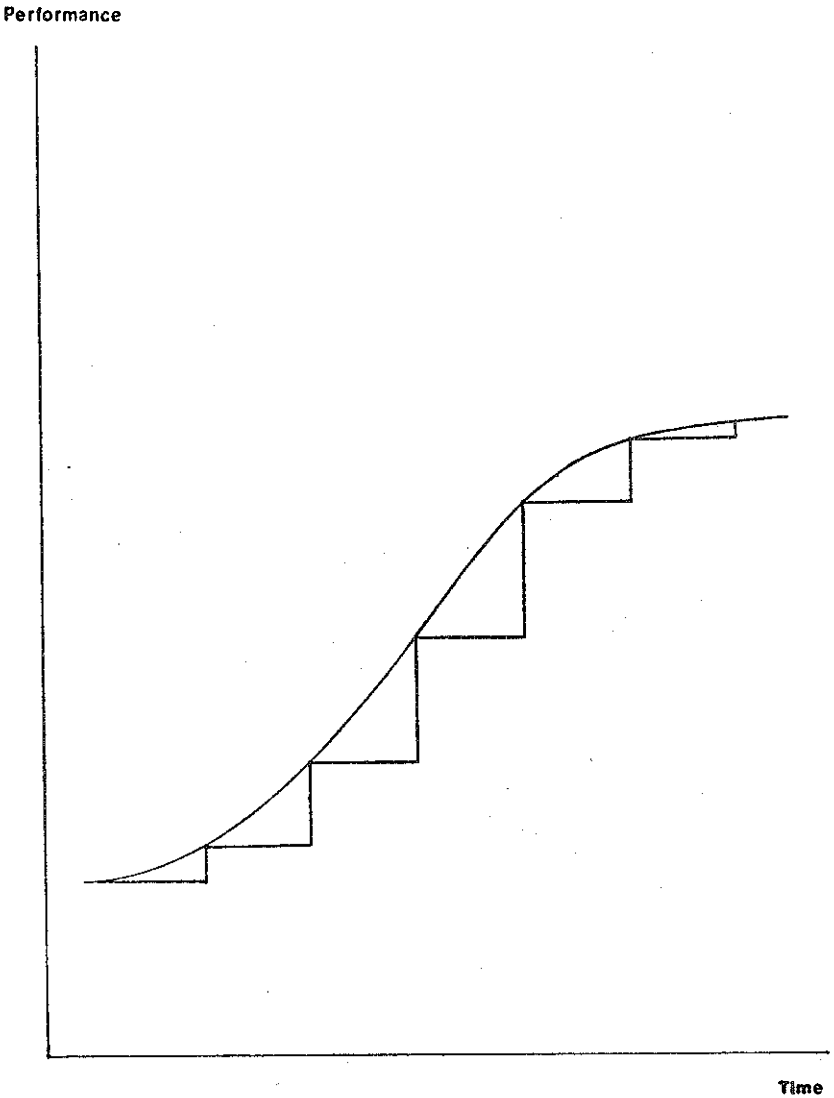


CHART 4

Continuous Replacement of Technologies

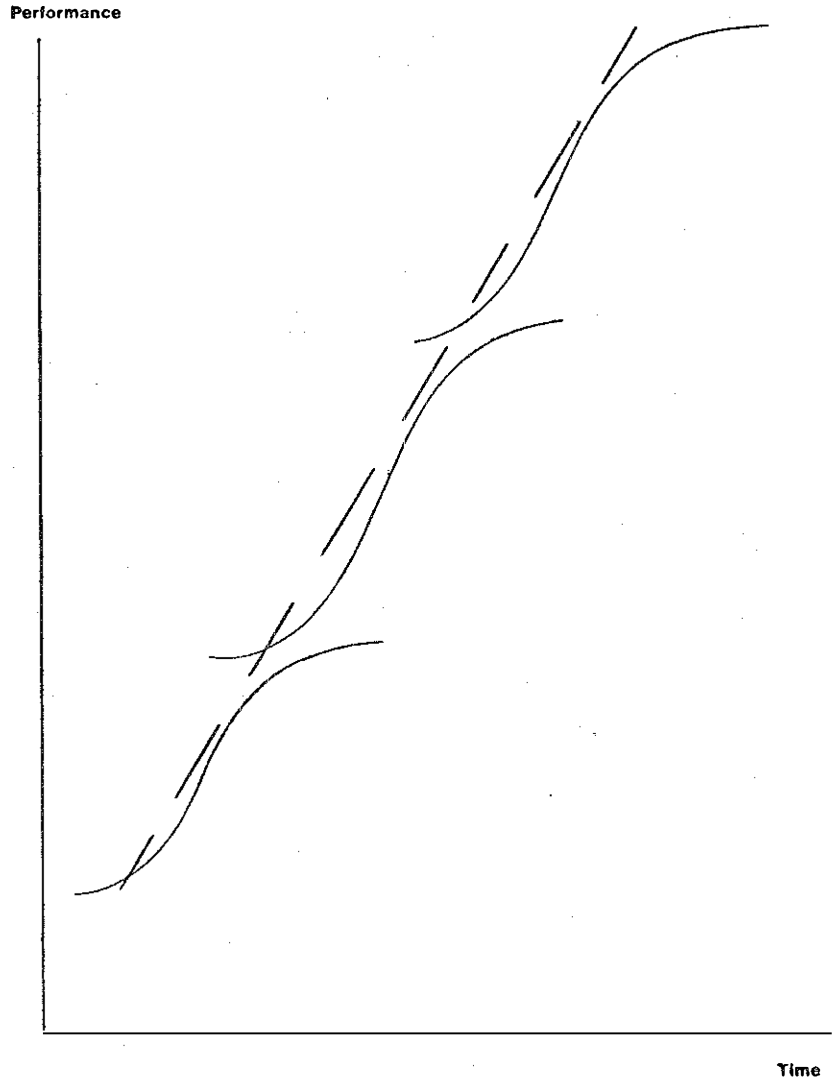
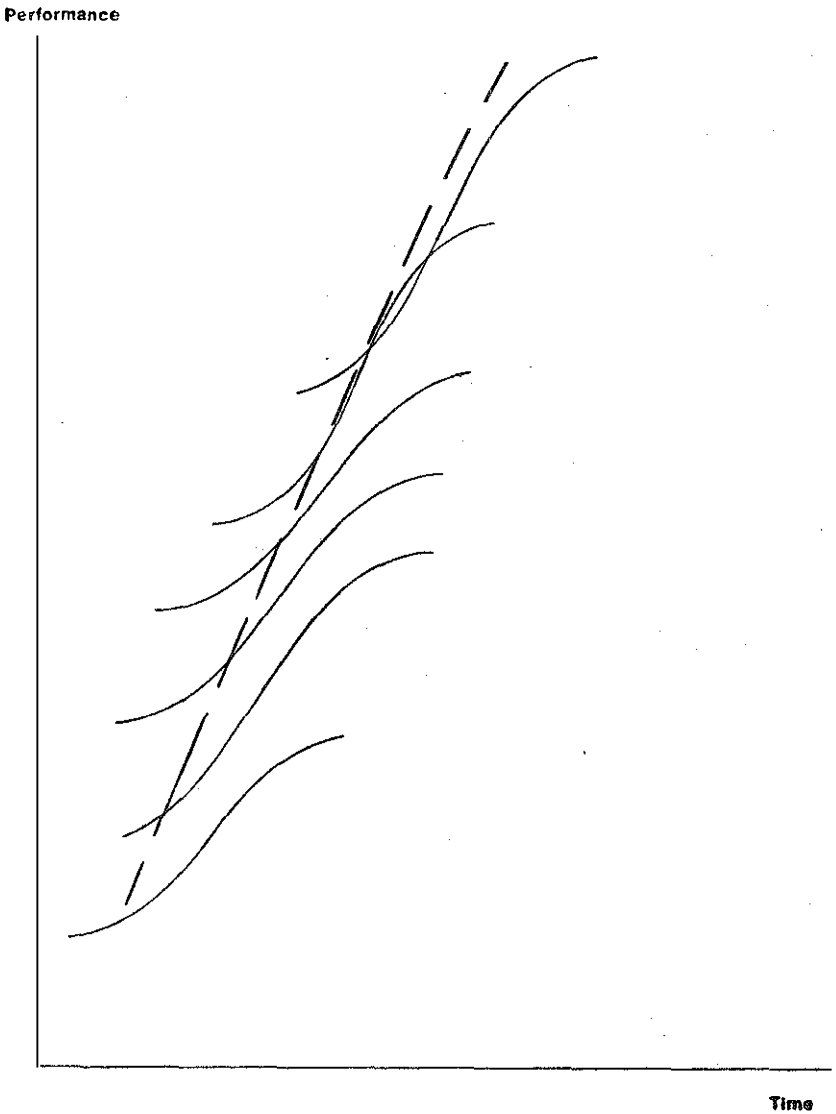


CHART 5

Overlapping S-Shaped Curves



uncertainties, "normal" behavior. In fact, it later will be shown that even when it comes to making substitutions it is impossible to simultaneously conserve microstability and macrostability -- that even in a world in which no discoveries are made there is a trade-off between micro- and macrostability.

III-2. Static Versus Dynamic Competition

The second major element in dynamic theory is dynamic competition -- a type of competition in which competitors cooperate by imposing risks upon each other. In this section two main points will be made: the first concerns how competition which leads to a diversity of ideas can promote macrostability. The second deals with an economy which, though it aims to be self-sufficient in ideas, it must be assumed there will be specialization among firms with respect to the degree of unpredictable behavior in which they engage.

III-2-a. Microdiversity Is the Hidden Hand of Macrostability

In static theory it is assumed that all competitors will display a zero degree of interaction. Where there are many firms, they will ignore their interactions with their competitors. And when there are few, firms will tend to take their interactions into account by limiting supply and charging monopolistic prices. But, even though under some conditions duopoly can lead to indeterminacy, the main feature of competition under static conditions is that it can produce no better results than can be achieved in a zero-sum game.

By contrast, when competitors impose substantial risks upon each other -- when competing with each other to detect and resolve dilemmas -- there is no way they can make probabilistic calculations of the risks involved. And because they cannot, I define dynamic competition as "competition under conditions of strong uncertainties."

Now, what must a competitor do if he hopes to survive in an industry in which the degree of interaction is very high? He obviously cannot take out insurance against such a risk. Therefore, he must hire imaginative entrepreneurs. And what is the output in a competition between imaginative entrepreneurs? The output is a diversity of ideas. Moreover, it should be emphasized it is because entrepreneurs cannot make probabilistic calculations of their technological and competitive risks that dynamic competition generates a diversity of ideas.

It is important to note, however, that whether the diversity of ideas generated is wide or narrow will depend on the degree of risk competitors impose on each other. When firms are dealing with highly unpredictable competitors, it will pay them to be highly unpredictable if they want to survive (e.g., the case of the chemical industry). On the other hand, in an industry in which a competitor takes only small risks, it will pay to be only slightly more unpredictable -- and the menu of alternatives will change more slowly (i.e., the case of the automobile industry). And in the limiting case -- close to a zero degree of risk -- where gasoline stations are located on four corners of an intersection, and symmetry of behavior rather than diversity of behavior will be the rule of the day. Thus, it may be assumed that the diversity of ideas generated will be a function of the degree of interaction.

But, how would we know whether a low degree of interaction was indicative of a low technological potential, rather than a low propensity to take risks? If we simply assume that the technological opportunities are bounded by what industries are doing at the moment, then our predictions will be wrong. In fact, in my book, Dynamic Economics, I looked into some fifty revitalizing inventions -- inventions which provided a relatively static industry with new S-shaped curves -- inventions such as the diesel locomotive, the jet engine, synthetic fibers and computerized machine tools -- and was unable to find a single case in which the revitalizing invention was produced by a major firm in the industry.[16] Actually, the only major industry which has not had to rely upon newcomers to the field for its discoveries is the chemical

industry. However, much longer than any other industry, the chemical industry has been characterized by a high degree of competition and a very wide diversity of ideas.

Therefore, when there is a low degree of interaction in a highly concentrated industry it simply cannot be assumed the reason is the lack of a real technological potential. And, if the industry in question cannot meet foreign competition, then we can be quite sure it prefers to cooperate by imposing risks upon the public at large.

Now, let us turn to the central question: what is the relationship between microbehavior and macrostability? In order to devise a predictive theory it is necessary to relate the ability of firms to deal with risks to their internal characteristics. However, the first important step in the argument consists of relating the diversity of ideas which an industry can generate to the degree of macrostability which can be attained.

As it happens, there are types of diversity associated with competition under both static and dynamic conditions: in the former case, diversity in the form of well-defined substitutes, and in the latter case, diversity of ideas which result from attempts to detect and resolve dilemmas. And each form of diversity implies a distinctly different concept of stability: diversity in the form of substitutes implies low variance outcomes; and diversity in the form of ideas, the ability to generate a smooth irreversible process.

Thus, Marshall's discovery of the concept of the elasticity of demand disclosed that the availability of substitutes can provide an economy with redundancy. The associated type of insurance provided by redundancy is static in nature: with a greater availability of substitutes, consumers and business firms are assured the possibilities of lower variance outcomes.

On the other hand, competition which promotes a diversity of ideas, say, in finding ways to reduce costs, provides a dynamic insurance policy for reducing the risks of inflation. And, whereas Daniel Bernoulli utilized his Uncle Jacob's law of large numbers to devise a static insurance principle, the same logic can be used to construct a dynamic insurance principle. When people buy fire insurance they bring the law of large numbers to their side in a once-and-for-all manner by converting strong uncertainties for the individual into weak uncertainties for the society. But, if risks are internalized to the appropriate degree, people and business firms can be motivated to generate a diversity of ideas for reducing the probability of fires. To be sure, not all the discoveries will be successful. But with a wide diversity of ideas we can bring the law of large numbers to our side for the purpose of generating smooth progress in reducing the probability of fires.

So, as far as smooth irreversible processes are concerned, this is the central conclusion: microdiversity is the hidden hand of macrostability! However, the rate will depend upon the degree of interaction. Suppose that we have a high degree of interaction between competitors and a reasonable amount of luck in making discoveries. Then progress in the industry is likely to be smooth and rapid (i.e., a high degree of macrostability). On the other hand, if the degree of interaction is low, then, instead of smooth fast history, we will have smooth slow history. But in either case, progress when plotted on a macroscale will be smooth.

In the following charts there are shown three fairly typical examples of smooth irreversible processes -- processes in which an enormous quantity of hints were used up by organizations possessing high degrees of openness to generate the technological options required for smooth progress. In the case of piston engine commercial airliners, it can be seen that after the DC-3 the rate of progress diminished. And

if a curve were plotted for jet engines, a new S-shaped curve would be obtained -- both in terms of costs and flying times. It is interesting to note the jet engine was developed by resolving a major scaling dilemma: turbine engines were initially developed for use in Swiss mines. Whittle took on the job of discovering a new kind of bone so they could be used in airplanes. The curves for jet engines to not show evidence of a diminishing rate of progress; but recently there has been definite evidence of a decline. In the case of computers, there is, as yet, no definite evidence of a leveling off in the rate of progress.

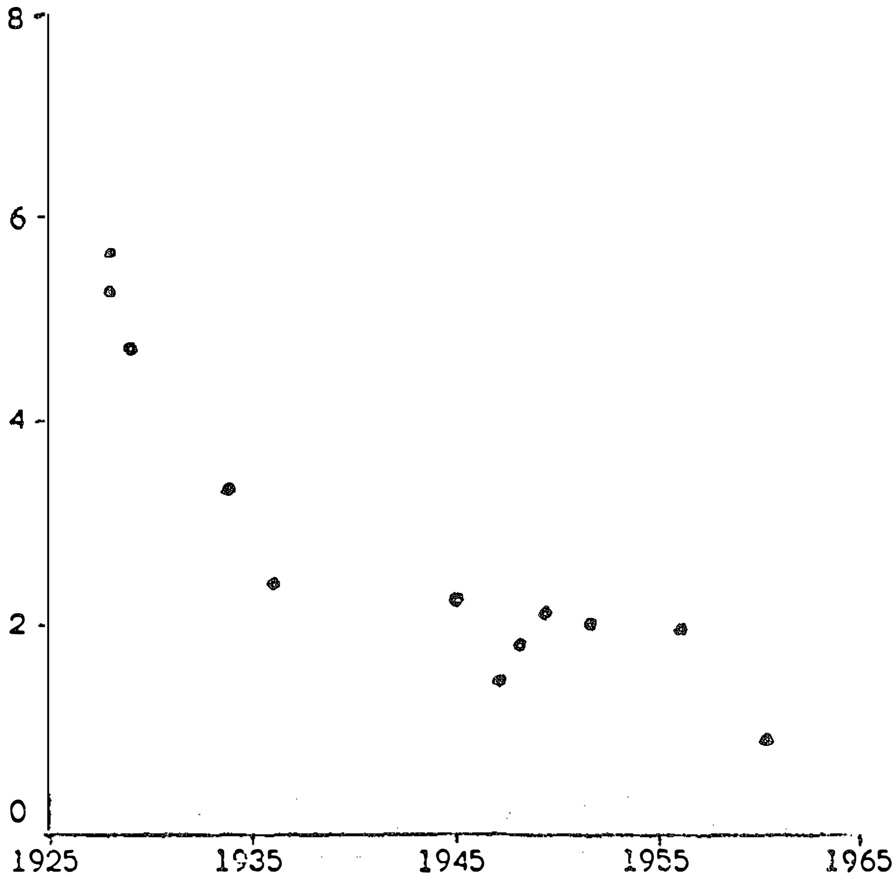
The important points to be emphasized, however, are these: first, without competition to generate a diversity of ideas, it simply would be impossible to explain the remarkably smooth progress shown in the last three charts. Second, look into the history of any of these projects and you will find their development was by no means smooth. Call it confusion on a microscale, small revolutions or anything you wish. But it is crystal clear that without a high degree of unpredictable microbehavior to generate a diversity of ideas, a high degree of macrostability simply could not have been obtained.

It is true, of course, when discussing competition which leads to a diversity of ideas that, in turn, can produce a high degree of macrostability we are not talking about competition presided over by Adam Smith's chief clerk in a pin mill, but, rather, competition between genuine entrepreneurs who must, best they can, weigh risks under conditions of strong uncertainties. Unfortunately, Adam Smith lived before the essential ideas in dynamic processes were regarded as common sense. Though his concept of the chief clerk has survived from generation to generation of economists, it certainly must be acknowledged that Adam Smith's great contribution to economics was "the concept of competition" -- and not the concept of a chief clerk. So, how can we do him greater honor than by constantly searching for

CHART 6

INDICATORS OF AIRLINER EFFICIENCY

OPERATING COSTS, INCLUDING DEPRECIATION
(cents per seat mile, 1960 prices)



FLYING TIMES: LOS ANGELES to NEW YORK
and CHICAGO to NEW YORK (hours)

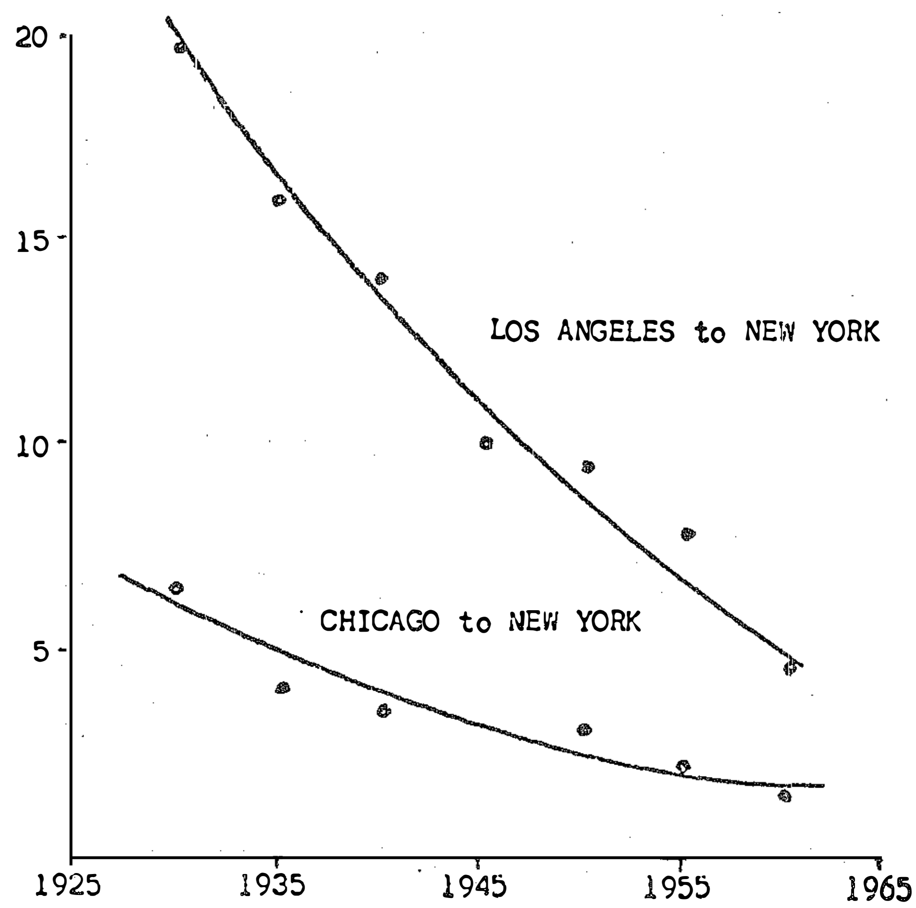
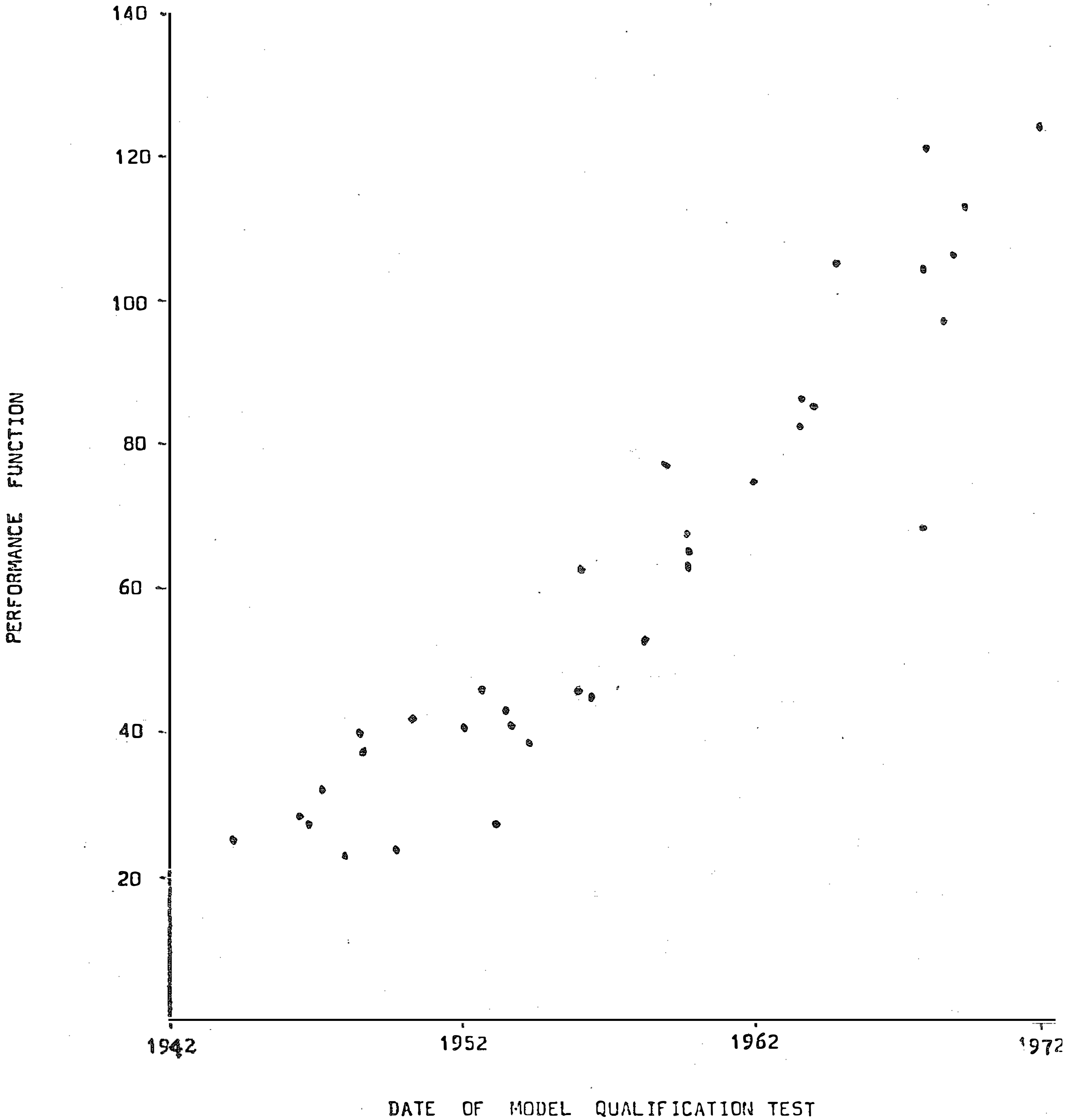


CHART 7

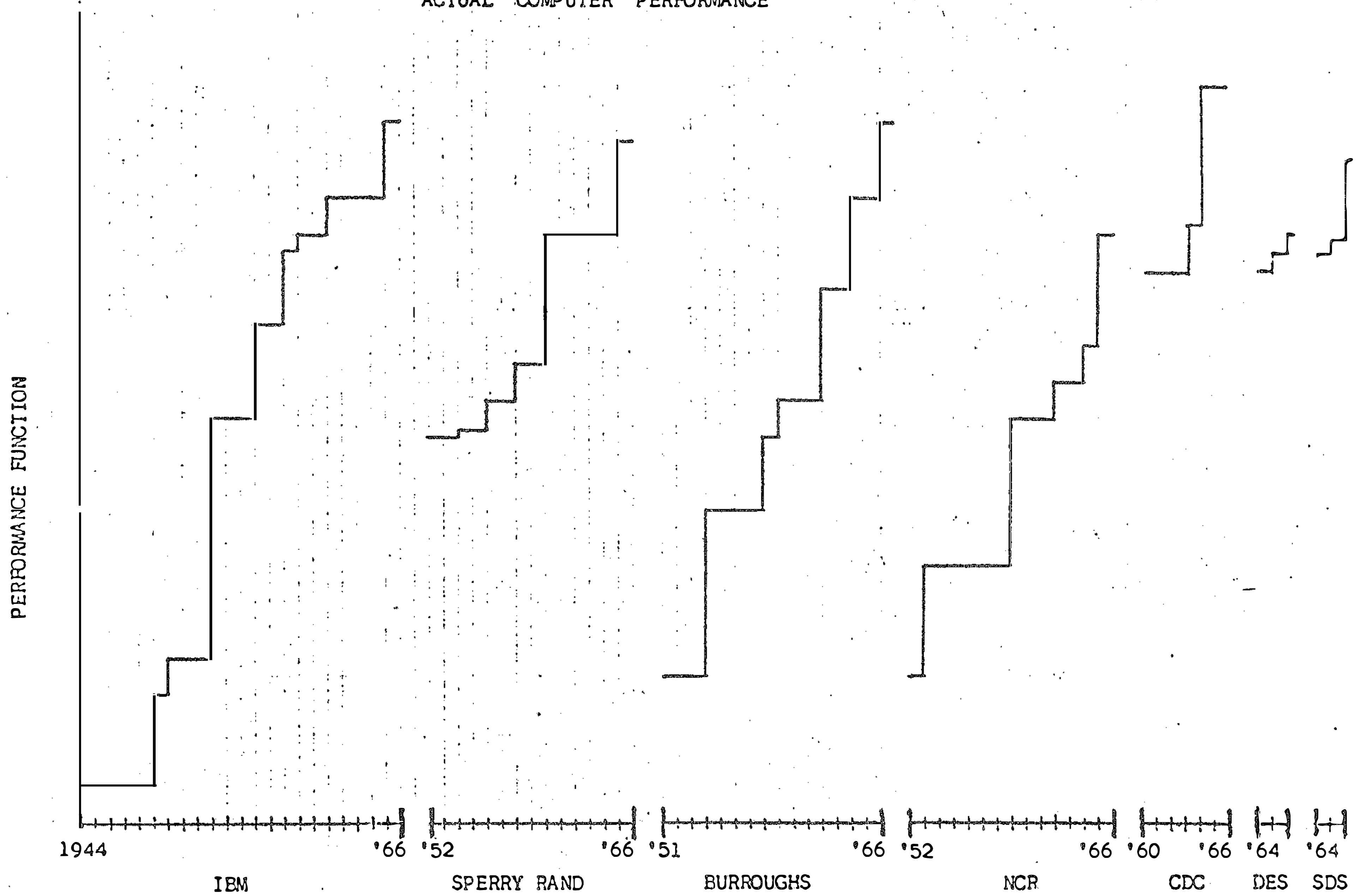
AIRCRAFT TURBINE ENGINE PERFORMANCE



Data taken from "Technological Change Through Product Improvement in Aircraft Turbine Engines" Robert Shishko, Rand Corporation, May 1973

CHART 8

ACTUAL COMPUTER PERFORMANCE



Data taken from <u>The International Computer Industry</u> by Alvin J. Harman, Harvard University Press, 1971 better arguments for competition? Moreover, it must be remembered Adam Smith was against tyranny of all kinds. And what better way to insure a society against tyranny than to insure it can generate a diversity of ideas?

III-2-b. Specialization in Risk-Taking

> If technology is to be employed efficiently and widely, and, indeed, if its own progress is to be stimulated by such use, institutional and ideological adjustments must be made to affect the proper use of innovations generated by the advancing stock of human knowledge. Simon Kuznets [17]

No organization has an unlimited ability to deal with strong uncertainties. In fact, I shall argue in the next section that the ability to engage in unpredictable behavior is a scarce commodity and must be conserved. Moreover, the task of being a good generator of ideas is so difficult there must be a division of labor between those who generate new ideas and those who borrow ideas. The entrepreneurs who generate new ideas are helped by clues from previous experiments. But only by using their imaginations can they generate new hypotheses (which may turn out to be good or bad). In other words, such entrepreneurs have no alternative but to pursue a "leap before you look" policy in generating new hypotheses, otherwise it would be impossible to overcome significant discontinuities. By contrast, entrepreneurs who borrow ideas operate mainly on a "look before you leap" policy. Now, it is true, of course, even a borrower of ideas can -- typically does -- encounter unanticipated problems, and must deal with dilemmas. But the dilemmas encountered in generating new hypotheses are more serious and more difficult to deal with. And for this reason there must be a division of labor between generators and borrowers of new ideas.

Consider, for example, Bell Telephone Laboratories and Western Electric, both of which are owned by AT&T. For many years the first was a specialist in generating a diversity of ideas and the the second, a specialist in applying the "look before you leap" principle.

Why did AT&T's success rest upon having within it quite different types of organizations? If there were only a Bell Telephone Laboratories we would have lots of marvelous ideas -- but it is quite unlikely we would have a dependable telephone system. On the other hand, if there were only a Western Electric, then we would have dependability, but with a slow rate of progress. Likewise, if the aircraft companies had operated their own airlines, progress might have been purchased at the expense of dependability; and if the aircraft companies had developed their own airliners, dependability at the expense of progress. Indeed, during the 1920s there was a joint ownership of aircraft and airline companies. But, inasmuch as they became separated, it is apparent there is an advantage in specializing in more or less predictable activities.

Along with specialization between generators and users of ideas is also cooperation. Quite obviously, it was necessary for Western Electric and the airline companies to make "institutional and ideological adjustments," if they were to make good use of the "advancing stock of knowledge." And conversely, the equipment which has been introduced into the telephone system and the airline companies can be looked upon as experiments, which provide clues to generate new ideas to make further progress.

And for this cooperation to occur there must be genuine pressures to internalize risks. In the case of airliners, competition between airline companies provides the mechanism to internalize risks the mechanism to assure there are eager customers for new ideas. In the case of AT&T, because of the long lag in reducing long distance and international rates, to take into account reductions in costs there was a real incentive to stay ahead of the rate makers. Moreover, there was also direct competition in building large microwave relay stations, underseas cables and communications satellites.

In the case of industries, such as the automobile industry, where the rate of progress is much slower, it is normally the sub-contractors who are responsible for the technological risk-taking. In fact, subcontracting has provided one of the principal mechanisms for generating a diversity of ideas in the American economy.

It can be seen, therefore, there is good reason to assume a division of labor between generators and borrowers of ideas: there is a trade-off between the promotion of dependability and the promotion of progress. Moreover, it also can be seen there is no Say's Law for ideas which will automatically assure either that supply will create its own demand, or demand, its own supply. Both conditions are important.

What does this mean in terms of an economy which hopes to remain dynamically stable by increasing total factor productivity at a more or less constant rate? It is true, of course, that United States firms can borrow ideas from abroad. However, for a country like the United States to become mainly dependent on foreign sources for its ideas would indicate it could not count upon a high degree of macro-stability in the future. Indeed, whereas it is generally assumed that we ought to become independent of foreign sources for our petroleum supplies, it would seem to be even more important for this country to continue to be self-sufficient in ideas.

And being self-sufficient in ideas, in turn, would involve having a diversity of firms with respect to their ability to engage in unpredictable behavior. To be more specific, Chart 9 portrays the present theory of the firm, a theory developed on the assumption of a fully exploited technology. And Chart 10 portrays a theory of the firm based upon an exploitable technology.

In both cases it is assumed that the ultimate judge of truth is the customer -- while you may be able to fool some of the people some of the time, you cannot fool all of the people all of the time. However,

CHART 9

A Fully-Exploited Technology

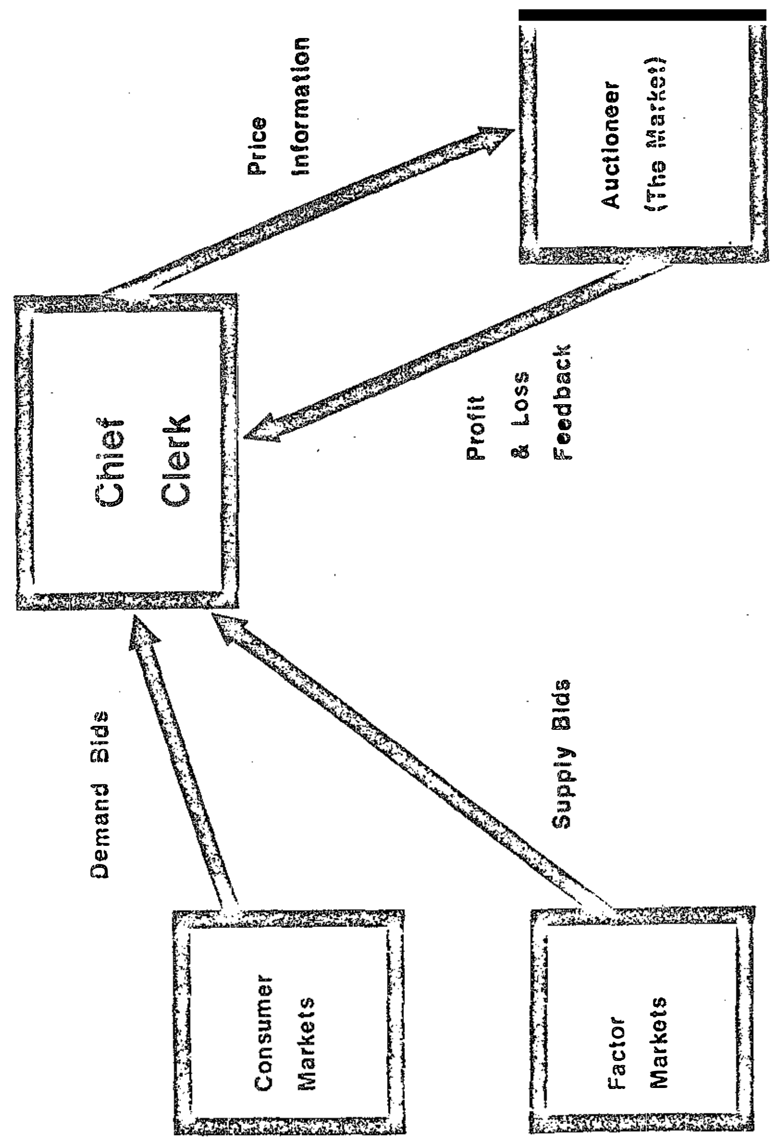
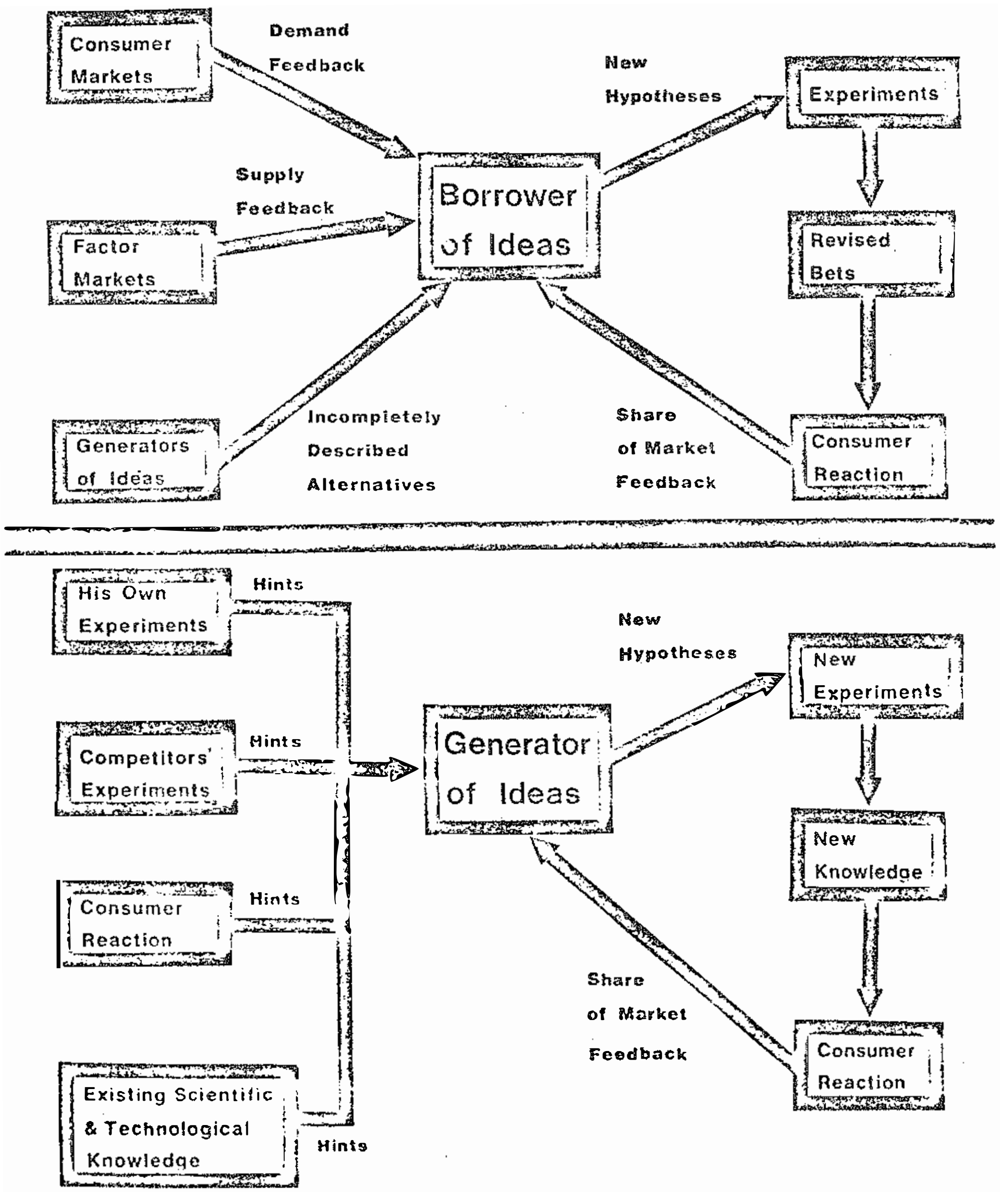


CHART 10

An Exploitable Technology



it should be apparent that in some markets competition in the form of creating new myths about the product can play a larger role than in others. So, while this assumption will be modified later, what we are really assuming is markets in which there is a reasonably objective basis for making judgments about quality.

The principal difference between the two theories of the firm is that, whereas the classical theory is based either on zero or weak uncertainties (i. e., a world which can be described in probabilistic terms), the second is based upon strong uncertainties. Consider, first, the chief clerk of a pin mill. As Chart 9 shows, he obtains demand bids from consumers, supply bids from factor markets, and from these generate price information to be turned over to an auctioneer (the market). The chief clerk may or may not do a good job in computing his supply prices. But if not, he will be informed in no uncertain terms in his profit and loss statement. In fact, if an economy consisted entirely of technologies which were fully exploited, then there is no reason why computers could not be substituted for chief clerks, and the entire job taken over by a centralized planning bureau.

However, even to a borrower of ideas, the world looks very different than it does to a chief clerk (Chart 10). In the first place, his information on new alternatives comes to him in the form of incompletely described alternatives, which is to say, alternatives with large variances. What this means is that on the one hand it is humanly impossible for borrowers of ideas to maximize their profits: they simply cannot be expected to know about all the incompletely described alternatives in the entire world. On the other hand, it also means that if they want to survive, the borrowers of new ideas must be constantly interacting with their outside environments to find out about new possibilities. And quite obviously, this type of search task cannot be turned over to a computer. Moreover, while at best, information on consumer demand may be supplied in the form of slowly changing probability distributions, at worse, there can be highly discontinuous changes in demand, indicating more ambiguous feedback signals. And such discontinuous changes in demand, in turn, can result in highly unpredictable types of microbehavior. For example, as a result of foreign competition, along with changes in demand for smaller automobiles brought about by rising fuel costs and inflation, the American automobile industry is now being forced to live with more uncertainty than ten years ago. And to make its own future more predictable, it has had to take actions no one could have predicted. For example, the stratified charge engine developed by the Japanese Honda Corporation provides a better compromise between fuel economy and a low emissions engine than did alternatives previously developed by the American automobile industry. But who could have predicted, say, ten years ago, that the Ford Motor Company would negotiate a technical assistance contract with Honda to help it develop such an engine? Indeed, anyone who has read Galbraith's arguments on the advantages of large size firms for the development of modern technology is surely convinced such a thing could not have happened here!

So we see, therefore, that whereas chief clerks deal with completely certain information, borrowers must be prepared for highly uncertain and discontinuous changes in their feedback. And on the basis of this feedback they must generate new hypotheses, and in the course of experiments find that their hypotheses were only partially correct. As engineers are fond of putting the point: "It's not what you don't know that kills you; it's what you think you do know!" On the basis of such experiments the bets are revised; the ultimate judge of "truth" is in fact measured in terms of the share of the market won or lost.

Now as far as the firms generating new ideas are concerned,

they must rely on even more ambiguous information: on hints. And to a much greater degree entrepreneurs must rely on their imagination to convert hints into new hypotheses. In fact, as will be explained more fully in the next section, it is the ability to use up hints to create new ideological mutations which constitutes "openness." Moreover, experiment plays a much larger role in generating new ideas, because ordinarily entrepreneurs must get married to and divorced from a succession of hypotheses before they find an acceptable resolution to a dilemma. Indeed, the principal distinction between firms engaged in generating ideas and those engaged in borrowing ideas is that the former tend to view all their activities and their competitor's activities as experiments which will reveal hints to make better experiments.

So it can be seen, therefore, that once we assume an economy can provide a high degree of macrostability, because it contains generators of ideas as well as borrowers of ideas, the economic system looks very different to us from the way it looked before: in an economic system in which there remain exploitable technologies, computers simply cannot be substituted for entrepreneurs. Indeed, the primary advantage of a dynamic capitalist society over socialism is that it can do what a computer cannot!

III-3. The Concept of Openness

As was pointed out earlier, the concept of "openness" plays two roles in dynamic economic theory. On the one hand, the seminal idea upon which it is based plays the same unifying role in dynamic theory as does the concept of specialization in classical theory. And on the other, once we acknowledge there are various degrees of openness, we have a link to relate the firm's ability to deal with technological and competitive risks to its external characteristics.

The Seminal Idea: The seminal idea upon which the concept of openness is based is a relatively simple one: in varying degrees, people possess the ability to "detach" hints from particular experiences, and utilize them to generate new ideological mutations, thereby making the whole greater than the sum of the parts. The significance of the concept is that without such a capability, man never would be able to interact with his outside environment to change the entire system (his own ideas plus the environment). Assume, for the moment, that all people acted as Bayesians. Bayesian probability theory is based on the paradigm of a semi-closed system (which assumes the outside environment is taken as a given).[18] And the uncertainty dealt with by Bayesian theory is how to adapt in terms of a given environment. Moreover, it is assumed that in pursuing a "look before you leap" policy by buying information, the underlying probability distributions are quite smooth -- so smooth it really does not make any difference which priors the entrepreneur initially selected.[19] In short, it is assumed that if all people were to act as Bayesians there would be no need for them to use their imaginations.

Now, if all people acted like Bayesians, they could be counted upon to utilize available opportunities for becoming more and more specialized in terms of a given environment. But, while their behavior would be highly predictable, in displaying such behavior they would make the world more unpredictable. Why? If his environment ever should change in an unpredictable way, Bayesian man never could detect, much less resolve, a dilemma. Half the battle in resolving a dilemma consists of being able to state it in a fairly precise way. And previous experiences can be important insofar as they provide hints. But unless an entrepreneur is willing to use his imagination to guess at new hypotheses -- guess in the sense he cannot attach probability estimates to the hypothesis until after he has made the guess -- then the hints from his experiences (or experiments) will go to waste.

Thus, while the Bayesians consider themselves to be the most

"scientific" members of the economic fraternity, the fact remains that if all scientists thought like Bayesians, by refusing to exercise their imaginations no new scientific laws ever would be discovered. As the point is made on the first page of The Feynman Lectures on Physics:

> Experiment is the sole judge of scientific "truth." But what is the source of knowledge? Where do the laws that are to be tested come from? Experiment, itself, helps to produce these laws, in the sense that it gives us hints. But also needed is imagination to create from these hints the great generalizations -- to guess at the wonderful, simple, but very strange patterns beneath them all, and then to experiment to check again whether we have made the right guess.[20]

And strange as it may seem, while guessing without being able to attach a probability estimate is a very unpredictable business, if scientists were unwilling to guess, the future of science (and scientists) would be much less predictable. Likewise, if engineers never were willing to resolve a scaling dilemma without attaching a prior probability estimate, they would remain a prisoner of their experiences.

In short, whereas increases in the degree of specialization tend to represent a highly predictable form of evolution, it is fortunate human evolution does not entirely take this form, because if it did, when reacting to completely new circumstances, man's future would be very unpredictable. This is not to say, however, that specialization does not play an important role in human progress. Since no one can hope to be an expert on everything, it is quite obvious there must be some degree of specialization. A completely unspecialized world -- a world of philosophers -- would be a world in which imagination was completely detached from reality. On the other hand, there is also little doubt that by reducing the diversity of a person's experiences specialization can narrow the scope for imagination. In fact, as the following quotation indicates, Adam Smith himself was aware of the limitations of specialization:

> The common ploughman, though generally regarded as the pattern of stupidity and ignorance, is seldom defective in his judgement and discretion. He is less accustomed, indeed, to social intercourse than the mechanic who lives in the town. His voice and language are more uncouth. . . . His understanding, however, being accustomed to consider a greater variety of objects, is generally much superior to that of the other, whose whole attention from morning to night is commonly occupied in performing one or two very simple operations.[21]

However, Thomas Jefferson was more of a radical than Adam Smith in three important respects. In the first place, his concept of stability was a dynamic concept. This is indicated by his often quoted statement about "constitutions":

> Some men look at Constitutions with sanctimonious reverence, and deem them like the ark and the covenant, too sacred to be touched. They ascribe to the men of the preceding age a wisdom more than human, and suppose what they did beyond amendment. I know that age well; I belonged to it and worked with it. It deserved well of its country. . . . But I know also, that laws and institutions must go hand in hand with the progress of the human mind. As that becomes more developed, more enlightened, as new discoveries are made, new truths disclosed, and manners and opinions change with the change in circumstances, institutions must advance to keep up with the times.[22]

Secondly, unlike not only Adam Smith, but practically all the members of the period of the Enlightenment, Jefferson believed it was possible for the human mind to become more enlightened. In fact, he regarded the people who believed the truths were all known as the "despots of the earth," and said, "For as long as we may think as we will, and speak as we think, the condition of man will proceed in improvement."[23] Third, in Jefferson's theory there was no automatic hidden hand. His theory of democracy was based on the assumptions there was a reciprocal relationship between man and his environment, that a highly interactive society could help promote the development of the individual, and with more enlightened individuals democracies would have a better chance of adapting to new circumstances (i.e., the concept of openness). However, he did not believe the process was

automatic. And to emphasize this point he preached for a small revolution every twenty years, because only by engaging in such unpredictable behavior could the future of democracies be made more predictable.

As was indicated earlier, Jefferson's thinking anticipates the seminal idea upon which modern biology is based. In the nineteenth century, biologists commonly believed all evolution was Darwinian: that evolution took the form of becoming increasingly specialized in terms of a given environment. But today it is believed that with respect to their openness there is more diversity within the races than between the races, and because of such diversity man is better prepared to deal with changes in his environment. C. D. Darlington makes the point as follows:

> Breeding varies . . . between the opposite poles of inbreeding and outbreeding. With inbreeding, heredity is all-powerful; determination is absolute: the group, the population, the caste or the race are invariable; they can be destroyed or removed but if they remain nothing can change them. With outbreeding heredity disintegrates; recombination produces unpredictable variability, endless innovation. Uncertainty, organized uncertainty, dominates not the organism but the population; determination in controlling evolution is transferred to the selective power of the environment. Between these two extremes, it now appears, every species of animal and plant is adapted to preserve some kind of balance.[24]

In other words, as in Jefferson's theory of democracy, up to a point diversity is the hidden hand of macrostability: as when an environment becomes so uncertain it loses its selective capability. Later in the discussion this point will be defined more precisely.

Finally, it is important to point out that biologists have, in turn, strongly influenced the thinking of modern post-Freudian psychologists. Psychologists used to believe man had a propensity only for security, but not for adventure and risk-taking. And they also believed man's personality was formed at a very early age, and could not be changed as a result of interactions with his environment. But the following quotation from the work of Erich Fromm will suggest a quite different kind of thinking:

> When an individual is born he is by no means faceless. Not only is he born with genetically determined temperamental and other inherited dispositions that have greater affinity to certain character traits than others, but prenatal events and birth itself form additional dispositions. . . . the formation and fixity of the character has to be understood in terms of a sliding scale; the individual begins life with certain qualities that dispose him to go in certain directions, but his personality is still malleable enough to allow the character to develop in many directions within the given framework. Every step in life narrows down the number of possible future outcomes . Eventually, the freedom of change becomes so minimal that only a miracle would seem capable of effecting a change.[25]

To conclude this part of the discussion: Openness consists of the ability to use up hints to generate new ideological mutations. Partly for genetic reasons, and partly due to reasons having to do with their environment, individuals greatly differ in their openness. And one reason we would like to see an economy with a wide diversity of firms is that providing freedom of choice to the individual means recognizing these differences. To assume that people are all alike in their requirements for security and adventure is quite as wrong as to assume that they all have the same preference functions. The other reason is that by providing an environment which recognizes the development of the individual, democracies can increase their freedom of choice when it comes to adapting to new circumstances.

The Relationship Between Openness and the Internal Characteristics of Organizations: As we already have seen, it is the ability of firms to generate a diversity of ideas which determines the degree of macrostability that can be achieved: the greater the discontinuities which must be overcome, the wider the diversity of ideas, and the greater degree of macrostability which can be achieved.

And it is openness which permits individuals to use hints to generate new ideas, thereby making the whole greater than the sum of the parts. Moreover, it should be apparent openness is a matter of degree rather than of kind. Openness is the ability to engage in unpredictable behavior. However, with respect not only to individuals, but also to organizations, there can be wide differences in the ability to engage in unpredictable behavior. At the one extreme there is an organization which possesses so high a degree of openness it is completely unpredictable. In other words, since it imposes no constraints upon its members it really is not an organization. At the other end of the extreme there is an organization which is so specialized it is utterly incapable of dealing with even a minor dilemma and is completely predictable.

Between these extremes there is an entire range of organizations classified in terms of their openness:

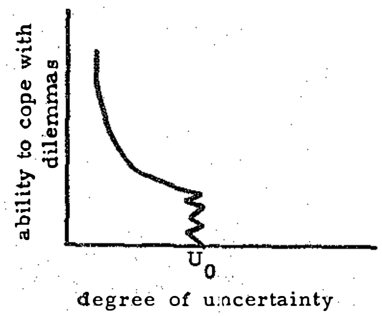
- Type I: The Generators of New Ideas
- Type II: The Borrowers
- Type III: The Profit Maximizers
- Type IV: The Risk Transmitters

Type I organizations must engage in a greater degree of unpredictable behavior than Type II organizations: they have, therefore, a greater requirement on "openness." This is usually evidenced by a greater degree of interaction with the universities. For example, computer companies are more interactive with universities than the insurance companies which use computers. And Type II firms tend to interact with a much larger variety of subcontractors than Type III firms -- the "pin mills" which have close to a zero requirement for openness. Obviously, the more specialized the organization, the more predictable its interactions with other organizations. Type IV organizations are former profit maximizers who have lost their ability to deal with unpredictability, and which, if they are to survive, therefore, must transmit the risk to others. Included in this category are business organizations who cooperate by imposing risks upon society at large, and labor unions which are able to conserve their microstability at the expense of the macrostability of society as a whole. For example, labor unions, which impose such a high degree of constraint on productivity gains as to make them practically impossible, transmit the risk for dealing with inflation to society at large.

Now, I will define an "equilibrium" in a more general sense than it is usually defined: an equilibrium means that the degree of technological and competitive risk with which firms must deal in an industry will remain more or less the same. And as long as the degree of risk remains the same we can assume that firms in the industry will exhibit more or less the same behavior. This does not mean firms will exhibit exactly the same behavior. Firms which have been successful in introducing a new product typically display a smaller degree of openness than those confronted with adversity. But what it does mean is that we should expect a higher average degree of openness on the part of Type I entrepreneurs than Type II entrepreneurs.

The purpose of making this assumption is to permit us to construct a concept of "the optimal degree of openness," taking as givens the initial degree of competitive and technological risk: assume that entrepreneurs in the industry in question have a fair idea of whether from their own point of view the dilemma in question is likely to be "minor," "challenging," or "very serious." Now, if it should decide to deal with only minor technological risks, it risks losing a market to a competitor. For example, a computer company which aimed to bring about only a 5 percent improvement in performance would be wasting its money, because on the basis of its previous experience in the industry it knows its competitors are likely to do a good deal better. So, balancing competitive and technological risks does not mean aiming

for an incremental improvement -- not in this market. On the other hand, the members of the firm also know the larger the advance, the greater the degree of uncertainty involved. In fact, it can be assumed that if any firm were compelled to deal with a greater and greater diversity of hints, after a point its dilemma-resolving capability would fall to zero:



So, what does the optimal degree of openness mean? In general terms, it means to be not so timid as to insure one's defeat -- but not so adventurous as to be driven off the precipice. And anyone acquainted with real world entrepreneurs will agree, I am sure, that what entrepreneurs do not do is to take unnecessary risks, which is to say they act to conserve their ability to deal with unpredictability.

Suppose, for example, someone has the choice of opening two doors. If he opens the one, a beautiful blond and a million dollars will greet him; if he opens the other, a poisoned dart and instant death will overtake him. Now, if he decides to make the choice by flipping a coin, he is not acting to conserve his ability to deal with unpredictability. Conserving one's ability to deal with unpredictability means regarding his hints as his most precious asset. Nor would an entrepreneur who narrows his supply of relevant hints by insisting upon selecting them from a domain which applies only to blue-eyed blonds who were good cooks would be acting to conserve his ability to deal with unpredictability, because if he values his life, he would be engaged in undertaking unnecessary risks.

The purpose of constructing the concept, "the optimal degree of openness," is twofold. In the first place, it permits us to consider a trade-off which has been implied in the previous discussion, but which has not been explicitly considered: the costs involved in making certain aspects of an activity more predictable as measured in terms of achieving a lower degree of predictability in other aspects: the uncertainty trade-off. In the second place, it provides a means to relate the openness of organizations to their internal characteristics. I will start with the uncertainty trade-off, because only by understanding this trade-off can we understand the relationship between the openness of organizations and their internal interest.

The Uncertainty Trade-Off: A few examples will make clear what I mean by "an uncertainty trade-off." Suppose in the example of the entrepreneur trying to choose between two doors, the entrepreneur insists upon a wife whose characteristics are highly predictable, and ignores all hints except as they apply to blue-eyed blonds who are good cooks. By imposing arbitrary constraints on his freedom of choice, he risks making his own life more unpredictable. Or suppose that someone decided to ignore uncertainty by not obeying traffic lights. Then by choosing to ignore uncertainty he would be making someone else's or his own life more unpredictable. Or, return to the example of heart operations. It has been found that a quick decision on the part of a nurse during the recuperation period can be vital in saving a person's life. But what would happen if nurses refused to take action without consulting a doctor? Then by making their own lives more predictable, they would be making their patients' chances of a successful recovery more unpredictable. Or suppose that in order

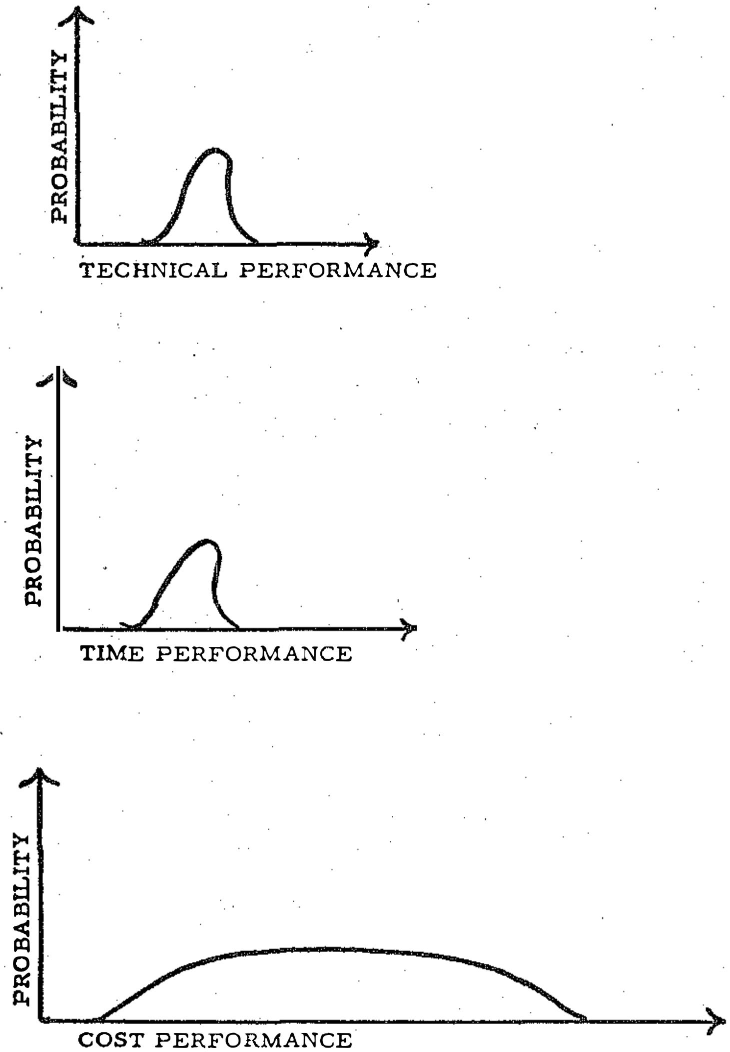
to make the lives of their members more predictable, labor unions should decide to resist the introduction of measures which would result in technological unemployment in the construction industry. Then, when it came to buying a house, young couples might find that their lives are more unpredictable. Conversely, in order for young couples to buy a house at a relatively low cost, the labor unions would have to give up some of their insistence upon predictability. Or suppose that in order to make growth more predictable, it was decided to use high sulfur fuels. Then growth is being made more predictable by introducing a greater degree of uncertainty into the environment, which, in turn, means that peoples' right to good health is being made more unpredictable. And, again, if the environment is to be made more predictable, then unpredictable behavior to discover alternatives to high sulfur fuels is required.

It should be apparent from these examples that the uncertainty trade-off can be a trade-off which affects a particular entrepreneur engaged in a particular activity -- or a trade-off which affects entire societies. But to simplify the discussion, let us start off with an uncertainty trade-off which affects only a single entrepreneur. Assume the entrepreneur in question would like to pin down the time when the development of the aircraft will be completed; and to do that he freezes the design. Now, he may be lucky. The airplane may perform just as he predicted it would. But he also may run into bad luck, and have to deal with a series of dilemmas he did not anticipate. So the cost of requiring a high degree of certainty in time and technological performance is to make for more uncertainty in his time performance (as is shown in Chart 11).

Now, if he actually knew the trade-off between time and cost beforehand, his problem would be a relatively simple one. Assume the uncertainty U(A) associated with a favorable outcome

Chart 11

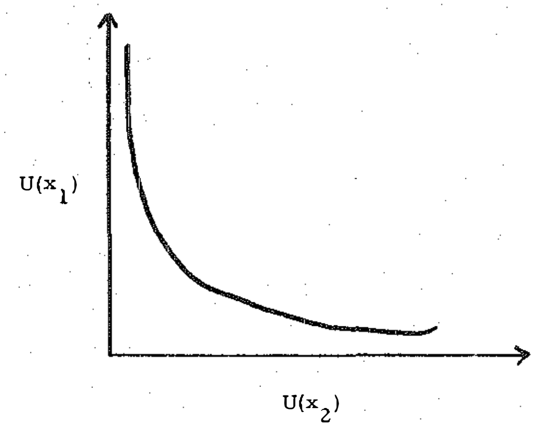
The Uncertainty Trade-Off



of the dilemma A facing the firm is:

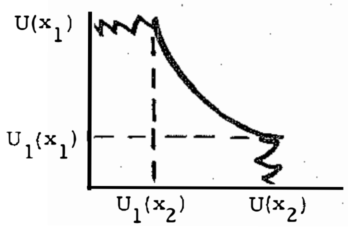
$$U(A) = KU(x_1)\ U(x_2) \qquad (1)$$

where K is a constant (that depends on initial conditions) and x_1 and x_2 are the factors upon which A depends. For example, x_1 can represent the initial cost goal and x_2 the initial time goal for building the airplane. On the basis of this assumption the trade-off between $U(x_1)$ and $U(x_2)$ would be smooth:



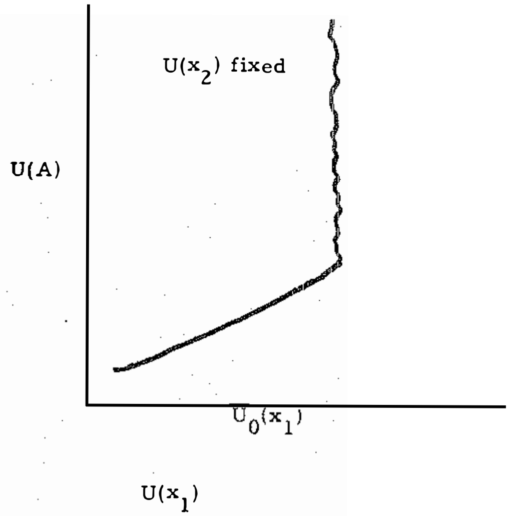
Now, if the trade-off were smooth, then the entrepreneur's problem would be a relatively simple one. He only would have to decide how much time was worth to him. However, while the trade-off shown is much like the one contained in the uncertainty principle in physics, once human beings are brought into the equation, we introduce strong uncertainties, which is to say, life becomes more complicated. To convince yourself the trade-off cannot be smooth where human beings are concerned, think of a contractor who desires to save time in the construction of a building, and thinks he knows the trade-off between his cost and time uncertainties. The contractor believes if more and more workers are added his initial cost estimates will be made more uncertain, because they will get in each other's way. In fact, he understands that if enough workers are added a point will be reached in which the outcome will be totally unpredictable, with people hitting each other with shovels -- a situation which can be described as an infinite amount of motion, but no movement. But what he does not know is just when in the process of adding more and more workers the process will become totally unpredictable. Once human beings are put into the equation, we are forced to acknowledge the world social scientists observe is a world of strong uncertainties.

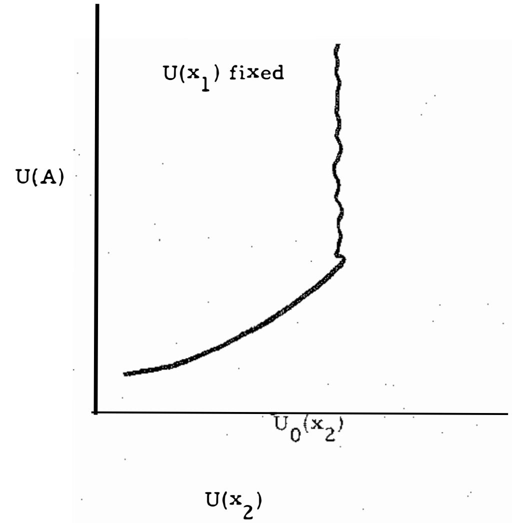
The entrepreneur in this case cannot see the trade-off curve in its entirety. Depending on the degree of uncertainty which is involved, he is in a position to understand the implications of the trade-off between time and cost uncertainty only within rather ill-defined limits:



Now, the entrepreneur engaged in choosing between two doors obviously would see a smaller portion of the curve than the entrepreneur who was trying to save time on a construction project.

But regardless of whether the portion is small or large, by placing artificial constraints the entrepreneur cannot demand less uncertainty than $U_1(x_2)$ in his initial time goal or less uncertainty than $U_1(x_1)$ in his initial cost target. Also, if it is assumed $U_0(x_1)$ is the maximum uncertainty in cost and $U_0(x_2)$ is the maximum uncertainty in time with which he can cope:





then it appears the process of minimizing U(A) defines an upper and a lower bound for the optimal uncertainty in the cost goal and the time target. Hence, a (successful) optimization process requires that:

$$U_1(x_1) < U(x_1) < U_0(x_1)$$

and (2)

$$U_1(x_2) < U(x_2) < U_0(x_2).$$

It is keeping within these bounds which constitutes the optimal degree of openness: recognizing that demanding less uncertainty in some aspects of an activity will result in more uncertainty in others, and that if too much predictability is demanded he simply may defeat his purpose. In real life the entrepreneur is constantly engaged in making these trade-offs, as he becomes married to and divorced from a whole series of hypotheses. And this is the fundamental reason why engaging in relatively low cost experiments is an important aspect of conserving his ability to engage in unpredictable behavior.

What if we were not considering a single action like developing an airplane, but rather a number of such actions? The principle would be the same. For example, if the Military Services seek a high degree of predictability in their time and performance goals, then the country must be prepared for a low degree of predictability in their cost estimates. And if the labor unions impose constraints to make the lives of their members more predictable, then they will make someone else's life less predictable. In a world of uncertainty it is impossible for society as a whole to conserve its microstability.

The uncertainty trade-off will, of course, depend on the degree of uncertainty involved: the greater the degree of uncertainty, the higher the price of insisting on a high degree of predictability. However, it easily can be shown that even in the case of statistical uncertainties a trade-off does exist. Mrs. Archie Bunker's macrostability objective, we will assume, is to live within her household budget and, if possible, to put aside a little pin money for her personal use (i.e., an entrepreneurial profit). And furthermore, for sake of the argument, assume although Archie adjusts her budget to take into account changes in the average cost of food, there are large day-to-day variances. So it is apparent that if she diligently searches for hints about bargains, it never can be predicted what she

will buy on a given day. Consequently, she is a predictably unpredictable system, subject to statistical uncertainties. Now suppose Archie truly enjoys microstability, and to insure his own life will be more predictable, he orders his wife to buy particular foods on special days. He simply cannot require more and more predictability without jeopardizing the macrostability of the household food budget. Nor can she decide to impose constraints to make her own life more predictable without making her quest for macrostability less predictable. Thus, imposing artificial constraints to make his life or her life more predictable will make the macrostability of the household food budget less predictable.

Hence, it is impossible to conserve microstability and macrostability simultaneously. And the same is true for the firm. If we measure macrostability in terms of profits, then it should be apparent that were the firm to try to conserve its microstability by failing to make substitutions the variance in profits would be much larger than if its goal were macrostability. Moreover, it should be apparent in both cases we are dealing with a type of behavior highly familiar to economists, namely, that described in Bayesian probability theory. Mrs. Bunker's prior probability distributions are provided by her tips; her posterior distributions, by the "experiments" she makes when she goes to the store. And, if either households or firms try to pin down the experiments which can be made so as to make their own lives more predictable, they will make outcomes less predictable as measured in terms of the day-to-day variations in their profits. Thus, even in the case of statistical uncertainties there is no way microstability and macrostability can be conserved simultaneously.

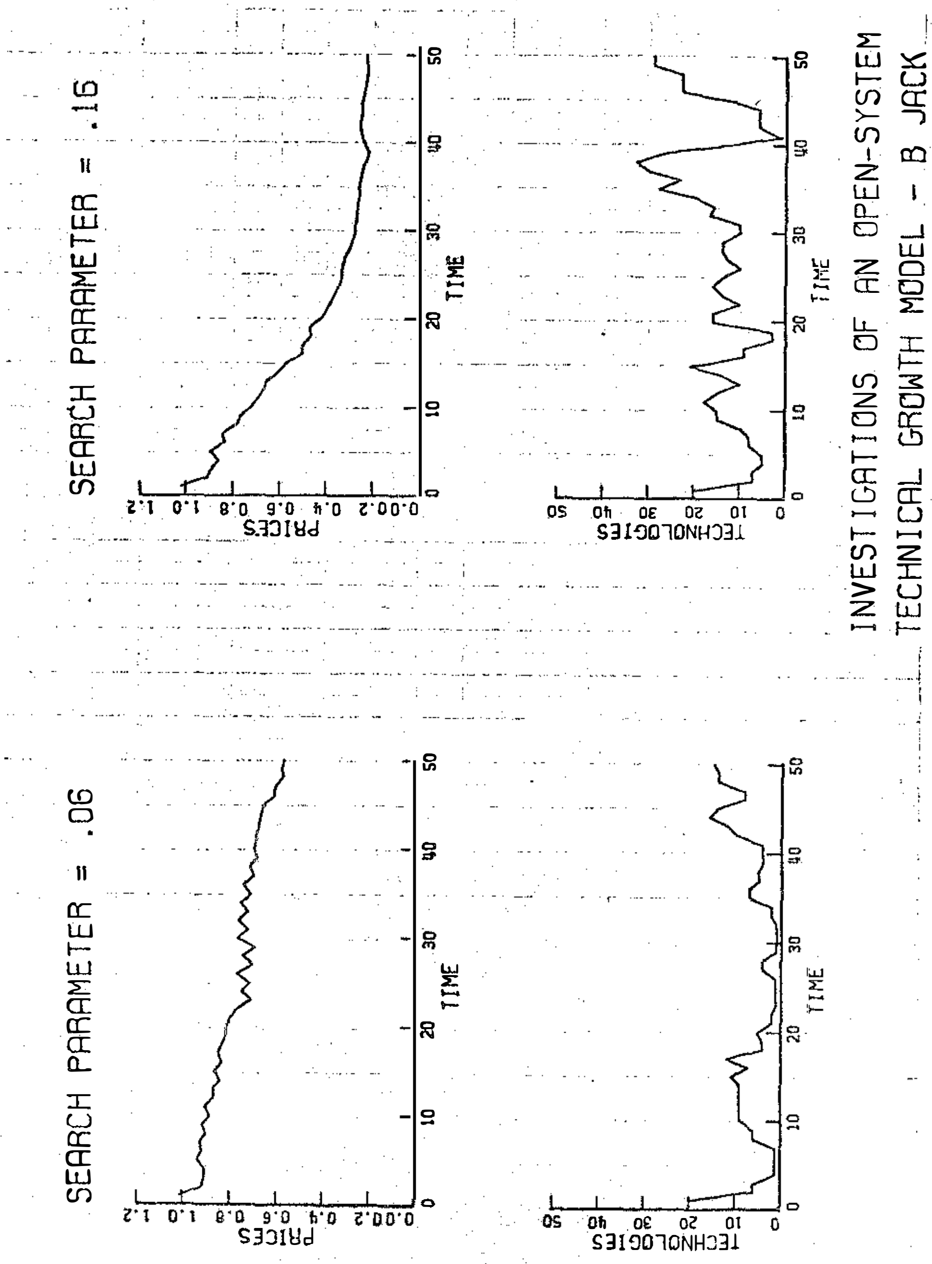
In the case of strong uncertainties, we should, of course, expect a larger uncertainty trade-off. To test this hypothesis, a student of mine made an experiment with a relatively simple computer simulation model. The model involved fifty firms, and assumed that the only two factors of production were labor and capital. In this model competitors did not compete to steal markets away from each other. Rather, it was assumed that the pressure for increases in productivity came from either higher wage demands or other increases in the price of inputs. Firms were assumed to satisfice in terms of some specific profit rate until input prices went up. Then they searched for ways to improve productivity. The term "technology" which appears on the following chart indicates a "technological recipe" and measures how widely or narrowly they searched. Macrostability was measured in terms of price stability over a fifty-year period. And the purpose of the experiment was to find out how sensitive macrostability was to changes in the search rate. Since a low search rate, in effect, related to a high preference for microstability, it can be seen that the trade-off is very large (see Chart 12).

The declines in the number of technological recipes reflect adoption of best available practices; increases reflect a search for a better menu.

<u>The Degree of Openness Versus the Internal Degree of Democracy</u>: Assume there are two communities which have decided they would prefer to deal with the risks involved in bringing about productivity gains rather than deal with the risks of inflation. And also assume that output per unit of input in one of the communities is increasing at just twice the rate of the other. What are the associated differences in microbehavior if it is assumed that both communities continue to bring about the same rate of productivity increase?

Assume the internal degree of democracy can be defined in terms of (a) the availability of imaginative people; and (b) the constraints imposed on their interactions. Also assume organizations can possess a wide diversity of people with respect to their openness, and that such a diversity can be measured on a diversity of people index on a scale

CHART 12



from zero to one: when the index is zero, people are only technically alive and have no capability whatsoever to generate a diversity of ideas; and when the index is one, they can generate a bewildering assortment of ideas.

The assumption that "openness" and "creativity" are positively correlated corresponds with the findings of a number of post-Freudian psychologists. The measure of openness is tolerance of ambiguity; and they have found that while intelligence (as measured by the standard intelligence tests) matters up to a certain threshold (which is different for different professions), beyond the threshold tolerance of ambiguity is a better predictor.[26] Not surprisingly, people with a high tolerance of ambiguity tend to have had a wide diversity of experiences.

Organizations exist mainly for the purpose of imposing constraints on their members. And an organization which imposed no constraints on its members would be incapable of resolving a dilemma. Therefore, we also can hypothesize a diversity of interactions index (D_p) on a scale from zero to one: when the index is zero, the interactions are entirely constrained, and human diversity goes completely to waste. When there are no constraints on the interactions, the organization features an infinite amount of movement but no motion: people have all sorts of interesting ideas, but the organization, as such, has no capability to resolve a dilemma.

Now, there are various ways to measure the diversity of the interactions. However, the best single measure I have been able to discover is the randomness in their communications: organizations in which the interactions are highly constrained possess little randomness in the communications.

Excellent examples of firms possessing a low degree of openness and very little randomness in their communications are to be found in the Cyert and March book, A Behavioral Theory of the Firm,[27]

in which was found communication went up and down, and organizations searched for new alternatives very narrowly. Indeed, this research is very much in the tradition initially established by Weber, because he too was primarily interested in highly structured firms optimized, so to speak, for the minimization of conflict. However, it may be assumed that if the computer companies had displayed the same type of behavior they never would have been able to use computers to run their simulations.

On the other hand, excellent examples of firms possessing both high and low degrees of openness are to be found in the Burns and Stalker book, The Management of Innovation.[28] My main difference with them is that they classify firms into two types -- "mechanistic" and "organic" (with the organic displaying a higher degree of internal democracy) -- whereas one should consider an entire spectrum of organizations in their capability to engage in dynamic behavior.

Actually, even more interesting examples of dynamic behavior than they relate are to be found in a type of R&D organization commonly known as a "skunkworks" -- an organization in which engineers work directly with machinists and an approach is followed that is both highly pragmatic and highly interactive. Thomas Edison is usually given credit for having discovered this type of organization. But it was also employed by Charles Kettering; and as far as the chemical industry is concerned, for many years skunkworks represented the standard operating procedure for pioneering new products. From the point of view of generating new ideas, a highly efficient organization is almost the direct antithesis of Weber's ideal organization (which was optimized for an unchanging external environment).[29]

It should be emphasized, though, that dynamic organizations contain not only a great deal of conflict on how to achieve certain generally accepted goals. They also contain a good deal of trust, because personal relationships predicated on achieving no worse results than in a zero-sum game are unlikely to achieve any better. And more randomness in the communications implies more trust than an organization whose internal relationships are highly structured. Indeed, the degree of trust is the indicator research managers themselves pay most attention to: when people say "I don't know, but let's find out," they feel the organization is healthy. But when the top echelon people expect definite answers to every question, then they regard trust in short supply.

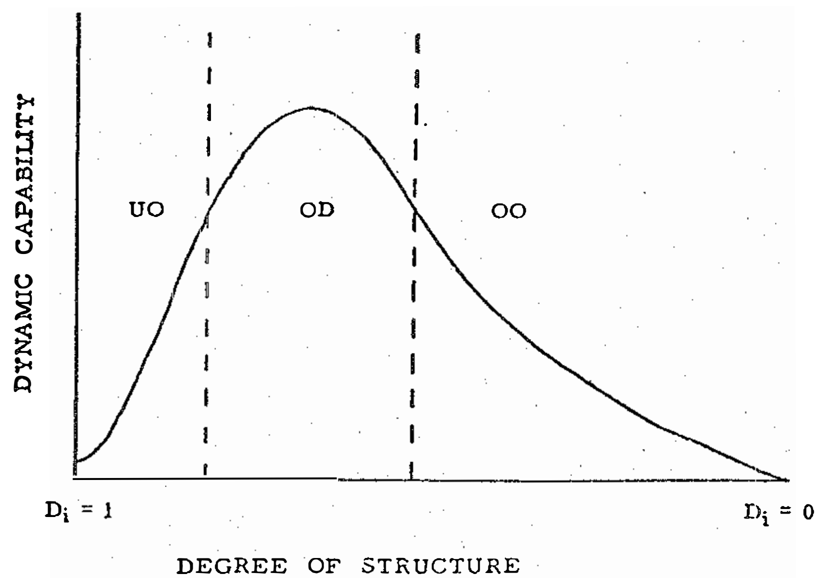
Consequently, it can be seen that the rate of progress depends on (a) diversity of people in terms of their openness; and (b) the diversity of the interactions. And these two factors define the internal degree of democracy of an organization. Moreover, also assume that fortuitous events can play an important role. Then, on the basis of the above definitions, we can say, in very general terms, that the rate of progress (ΔE) is a function of the diversity of people (D_p), the diversity of their interactions (D_i) and luck (L) or:

$$\Delta E = f(D_p, \; D_i; \; L)$$

Now, to return to the main question: How can an organization be optimized for dealing with a high degree of risk in its external environment and, therefore, for rapid progress? Budget permitting, obviously a wide diversity of people would be advantageous, with not all at the upper end of the scale. If there were only imaginative people, we would obtain many marvelous ideas -- but it is unlikely the airplane would fly. On the other hand, if we had only unimaginative people, it would be impossible to make any new history. So, while overcoming larger discontinuities imposes a greater requirement on imaginative people than overcoming minor discontinuities, even when pioneering new technologies it would be desirous to have more and less imaginative people.

Next, what happens to the degree of constraint when it is imposed on people's interactions? If the D_i index were 1, the interactions would be completely unconstrained; and it would be impossible to bring order out of chaos (i.e., the state of unorganized organization [UO]). On the other hand, if the index were O, the organization would be incapable of engaging in any unpredictable behavior. And if the relationship is plotted between the dynamic capability of the organization and its internal degree of structure, we would have the following type of curve:

CHART 13



As the chart indicates, the organization is optimized for a high rate of progress when it is in the state of organized disorganization (OD) -- a state in which maximum advantage is taken of human diversity, because the only constraints imposed on the interactions are those imposed by the overall mission of the organization. With no constraints on the interactions it is a completely unpredictable organization (UO). On the other hand, with the interactions completely prescribed, it is a completely predictable organized organization (OO). And when the organization is in the state of organized disorganization (OD), it is in the best position to put luck on its side: if it is in the state of unorganized organization, only luck can bring order out of chaos. And if it is in the state of highly organized organization, its ability to detect and resolve a dilemma will depend mainly on luck, which is to say, it will possess a low degree of dynamic stability.

The reason the state of organized disorganization corresponds to the optimal degree of openness is this: to detect and resolve a dilemma in its external environment an organization must possess the capability to rapidly restructure itself in the light of new circumstances (e.g., as in the example of Mrs. Bunker). And as an organization becomes more and more structured, the less likely it will be able to perceive negative feedback, let alone resolve dilemmas.

It must be emphasized, however, the matter of the optimal degree of organization cannot be divorced from the degree of uncertainty in the external environment of the organization. If we think of interactive organizations as democratic organizations, then it can be said, when the seas are stormy, macrostability will require a higher degree of unpredictable microbehavior, and when calm, no diversity of behavior will be necessary. In fact, if ΔE is to be kept at zero, then either a society would be required which generated a zero diversity of ideas or was ruled by a dictator who imposed such tight constraints that all diversity went to waste (i.e., $d_p = O$, or $d_i = O$).

The conclusion: the demand conditions for progress are determined by the degree of competitive and technological risk in the various industries; and the corresponding "supply" conditions are

determined by the internal degree of democracy. It can be assumed that the lower the rate of progress in the industry in question, the lower the degree of democracy as measured by, say, the randomness of the communications. In other words, there is no Say's Law for ideas. Supply neither automatically creates demand nor does demand automatically create supply. Imaginative people may be available in firms, but if they engage in little dynamic competition (i.e., a low degree of interaction) diversity will go to waste. Or there may be genuine opportunities for progress; but if people are overly constrained (i.e., a low d_i) diversity also will go to waste.

What can we say about a world in which $\Delta E = O$, a world in which there is no progress, and all firms are assumed to be in an equilibrium with an unchanging outside environment? Logically speaking, there is nothing wrong with the classical theory of an equilibrium. Nor is there anything wrong with the classical law of supply and demand, providing it is assumed the economic system is closed, which is to say, demand and supply curves are taken as givens. In a closed system, the classical law of supply and demand will make very good predictions, indeed. And in real world markets approximating those conditions good predictions can be made. However, to assume that all firms are in an equilibrium with an unchanging external environment, and that the law of supply and demand generally holds, is to assume either an imaginary dilemmaless world (imaginary, because it is inconsistent with the laws of nature) for which all the alternatives are fully known ($\Delta E = O$) or a world with no human diversity (i.e., $dp = O$).

Actually, given the fact there is a diversity of people in the world, and new dilemmas are constantly arising, all societies must have a history -- whether it be a history in discovering new truths or new myths. Even the so-called "primitive equilibrium societies" do have a very rich history in myths! But they hardly can be called "democratic" societies, because they waste their diversity.

So let us now return to reality. Which conditions are the cause and which the effect? In dynamic theory it is impossible to neatly separate cause and effect. Thus, the necessity of surviving in an environment of high risks can cause firms to become highly interactive within. On the other hand, a high degree of internal structure can have the effect of preventing firms from dealing with a higher degree of risk. This is because increases in the degree of organization tend to be quite irreversible -- it is easier to become organized than disorganized! Indeed, this is the more fundamental reason why economists should be genuinely concerned when the rate of productivity increase declines in a country. Whether one is concerned with increasing productivity gains or lowering the rate of environmental degradation, highly structured firms cannot deal with unpredictability.

IV. POLICY IMPLICATIONS

No one can prove that we face a chronic inflation problem in this country, just as during the Great Depression no one could prove prosperity was not right around the corner. However, I think events will prove we do face such a problem, and for the following reasons: a decline in the ability of business firms to deal with risk and uncertainty; the increasing preoccupation of the labor unions with microstability; and the so-called stable growth policies pursued by the government.

<u>A Decline in the Ability of Business Firms to Deal With Uncertainty and Risk</u>: The post-World War II industrial revolutions in computers, communications, television, synthetic fibers, commercial aircraft and computerized machine tools generated a good deal of competition to exploit new technological gold mines. The fact that major technological advances tend to come in bunches is not, of course, something that is new in American history. In fact, Kuznets and Schumpeter, among others, have given this bunching primary emphasis

in their explanations of the "long waves" in economic activities. In fact, what distinguishes the post-World War II industrial revolutions from earlier ones is that they were so widespread, and involved a large segment of United States industry.

The fact we were a technological leader for roughly a half century meant, in turn, that in trading with the rest of the world we exported goods with a relatively high unpredictability content, imported goods with a relatively high predictability content -- and had a relative advantage in organized disorganization.

However, the loss of our technological leadership is a reflection of the fact that the postwar revolutions in technology are dying out, that is, with the major exception of the computer industry. And a loss of our technological leadership, in turn, has meant a decline in the openness of American firms, and an increasing degree of internal structure. The decline in openness is reflected by the much smaller degree of interaction between universities and business firms -- something which has alarmed both deans of engineering schools and business leaders. The increase in the internal degree of bureaucracy is reflected in the growing student dissatisfaction with large business firms. For example, whereas in 1955, 80 percent of Caltech graduates taking first positions went into business firms, today the corresponding ratio is only 20 percent. And almost all of these are going to relatively small firms. Going back for a period of about thirty-five years, a very good indicator of where the technological revolutions are is where the students are going! For example, during the 1930s the aircraft industry drew many students, and during the 1920s, so did the automobile industry.

So, what the dying out of the postwar revolutions really means is a diminution of the ability of United States firms to deal with risk and uncertainty: fewer opportunities for adventure. This means not only a poorer ability to bring about productivity gains in this country, but in other countries of the world. For example, the Canadians are trying to deal with their chronic inflation problem by initiating public R&D programs to increase the rate of productivity advance. However, if the fundamental problem is the inability of Canadian industry to deal with risk and uncertainty, it is doubtful if much will come out of this effort. In providing competition for Canadian firms, we provided the equivalent of a highly effective antitrust division. And that is where the basic problem lies, because it is competition which determines the demand for new ideas.

As far as this country is concerned, the problem is to determine how to prevent such a decline in competition from occurring that we find ourselves in the same position as Britain: a country which has little or no ability to search for or exploit new technological potentials. But for this country this is not a new problem. The trust movement of the 1890s reflected the same tendency of business firms to turn towards empire-building when they could not deal with problems at home, as we are witnessing today. And in the campaign of 1912, one of the major issues debated by Louis Brandeis was whether this country should regulate monopoly or promote competition. The main difference between now and then is that we now live in a more interconnected world, which means that competition is all the more important as far as macrostability is concerned.

The Quest of the Labor Unions for Microstability: Bargaining for higher wages does not necessarily threaten the macrostability of a country. Indeed, it can be argued the demand for higher wages has played the same role in stimulating advances in productivity as has competition. However, to an increasing degree the labor unions in this country are imposing constraints on productivity gains to protect a way of life. And the effect of such constraints is to reduce the ability of business firms to bring about productivity gains, even when the

conditions are favorable for competition and risk-taking. Consider, for example, the construction industry, which encompasses a large number of firms whose innovative behavior is highly constrained due to the labor unions and building codes. And consider the trucking industry, which in its featherbedding practices is becoming more and more like the railroads.

The desire of the labor unions to protect the security of their members is, of course, quite understandable. We do live in a highly specialized economy; and as people become more and more specialized, they become less and less able to deal with unpredictability. For example, for someone who has been a printer all of his life or is a highly specialized toolmaker, the cost of progress can be very high, indeed. And most economists agree that if we are to preserve a dynamic society, the issues of humanitarianism must be separated from the issues of progress. However, it is much easier to say this ought to be done than to determine how it should be done.

The Stable Growth Policies of the Government: What stable growth has come to mean is protecting the microstability of business firms and labor unions. And if we lived in an imaginary, dilemmaless world, then there would be no question that the promotion of microstability would result in the promotion of macrostability. However, as we have seen, macrostability is promoted by a high degree of unpredictable microbehavior. So, while governments may think they are promoting stability, in reality they are promoting instability! What stable growth policies really amount to is a prescription to make the United States economy into one which features the same degree of microstability as the British economy.

Furthermore, it must be remembered we do not only face the need to bring about productivity gains at a more rapid rate: we also face adapting our society to a new set of environmental constraints and energy shortages as a permanent way of life. Many people talk about "cleaning up the environment" as if it were a once-and-for-all job. But the fact of the matter is that whenever certain ill-defined rates of biological or physical irreversibilities are exceeded, serious environmental degradation problems will result.

Thus, the real problem facing this country is how to bring about more rapid advances in productivity while making smooth progress when dealing with the environmental issues -- progress which will require adjustments throughout the economic system. Furthermore, there is no way of avoiding these problems: if industry manages to conserve its predictability, the cities will be made more unpredictable.

Needed Research: I am confident dynamic theory ultimately will have the same impact on economics as it has had in the fields of chemistry and biology. How can an economic system be described without taking "openness" into account? However, I am also sure that no more than in those fields will the revolutions be made in a day.

Quite obviously, economists cannot decide whether the appropriate goal for a society is macrostability or microstability. Who are we to say societies ought to exist for the living rather than for the dead? What we can do is to do research which would (1) provide policymakers and the public at large with a better picture of the trade-offs between micro- and macrostability; and (2) provide them with research on the issues involved in increasing the dynamic behavior of various sectors of the economy. Research which would contribute to these purposes is as follows:

Measures of Dynamic Performance: Obviously, we would like to have quantitative measures of both the rate of progress and of the inputs to dynamic processes (e.g., the degree of randomness in the internal communications). Ideally, what we would like to know is the rate total factor productivity is increasing industry by industry,

and the particular industries or sectors of industry which are the main suppliers of new knowledge. For example, more information is needed on the importance of subcontractors as suppliers of new knowledge.

As for the internal characteristics of organizations, psychologists have devised tests for measuring tolerance of ambiguity (i.e., "openness"), and have found that in several dynamic corporations it provides a better predictor of who will make it into the middle management than the standard intelligence tests. But what is even more needed is some way, even if it is a very rough way, to measure the internal interactions of organizations. Needed, in other words, is a way to measure what social anthropologists observe.

Response to Increases in the Degree of Risk and Uncertainty: Assume that firms remain in an equilibrium with their outside environments in the sense that the degree of competitive and technological risk does not change significantly. Then we can predict that when the internal degree of risk is high, so will the internal degree of democracy be high; and when it is low, the firm will be more highly structured. Anyone who has visited a research and development organization in the automobile industry and, say, the computer industry can tell the difference. In highly structured organizations, ambiguity simply is not tolerated. Moreover, we also know the internal incentives of firms are adjusted to make them better able or worse able to deal with risk and uncertainty. For example, the chemical industry and the computer industry deliberately feature a good deal of internal competition -- competition in ideas. Thus, IBM makes its subsidiaries all over the world compete with each other. The test for the subsidiary in Britain is not how well it did in terms of its British competitor, but how well it did in terms of the best comparable American establishment. The petroleum industry does not feature internal competition. But it does have professional "skunks" in the top management to remind the vice-presidents they live in a world of strong uncertainties. And in the automobile industry the internal incentives are structured in a way so that advancement depends on ability to protect the organization from risk. For example, employees' benefits are computed in a way so that leaving the firm becomes increasingly expensive.

But what we do not understand at all well is the dynamics involved when organizations must become adjusted to a higher degree of risk: what limits these processes? We do know the adjustments typically seem more difficult in prospect than they do in retrospect. Furthermore, we know that, while small increases in the degree of risk will have no significant effect on behavior, when the changes become significant, highly discontinuous changes do occur. For example, airline companies will not change their affiliations to buy an aircraft which is, say, 5 percent cheaper than the airplanes they are now using. But when the difference gets to be about 15 percent, competitive pressures result in a very substantial change in affiliations. In fact, firms engaged in developing commercial aircraft use 15 percent as a rule of thumb figure when deciding whether to develop a new plane. What we do not understand is the process which occurs in airline companies when they change their affiliations. To be sure, once the process has started, competitive pressures force other companies to follow suit. However, if you had to bet on which airline company would be willing to make the plunge first, what would you want to know about the internal characteristics of the companies? What particular internal characteristics facilitate dealing with a higher degree of risk and uncertainty, and what are the trade-offs involved?

These questions are at the heart of many public policy issues. For example, if one considers effluent taxes as taxes to better internalize risks, then it obviously would be desirable to know more than we do today about the macroscopic effects likely to be produced by increasing

the rates. Obviously, if the agency engaged in administering such a tax had complete freedom, it could experiment with the rates until it achieved the desired performance. But given the opposition to changes in tax rates, this happens to be a field in which the "cost" of experimentation is very high. So, granting it probably would be impossible to make highly accurate predictions, we still would like the ability to make better informed rather than worse informed guesses. The problems of the environment will be with us forever. And the alternative to better incentives to internalize risks is direct regulation, which does not get at the basic problem of improving performance nor make profits a function of performance. Therefore, if the promotion of competition is regarded as a more desirable instrument than regulation, we need to know more about how incentives designed to increase the degree of risk internalization are likely to affect openness and the degree of dynamic behavior.

Another important policy issue -- perhaps the most important policy issue of our times -- is how to structure public organizations to increase their dynamic capability: their capability to engage in unpredictable behavior when the outside environment changes. It would be nice, of course, if there were an automatic hidden hand to internalize risks so that public organizations could be counted upon to be predictably unpredictable. Unfortunately, however, there is no such hidden hand. The question arises, therefore: how can they be structured to take into account not only information about new technological opportunities, but also changes in the wishes of the people? For the most part, public organizations generate a low diversity of ideas, and seem to be biased in representing particular types of interests. How, then, does one structure such organizations so they are better representative of the diversity of ideas in society at large? What are the particular factors which limit their openness? And what types of incentives are required?

The Promotion of Competition: Say that you want to regulate some industry from the point of view of preventing prices from increasing "too rapidly." How do you do it? In order to know whether the industry is doing a good job in exploiting its technological possibilities, obviously some knowledge would be needed of the possibilities. How do you obtain it? You might set up your own research and development organization to compete with industry. Brandeis, for example, once suggested that the ICC should set up its own equivalent of the agricultural experimental stations. Or some way might be found to increase the dynamic performance of industry so you could have a greater diversity of alternatives to compare. But once either alternative is considered, we are considering the promotion of competition rather than the regulation of monopoly.

The main problem with "regulation," as it has been practiced in this country, is that it does not do either one of these things. Quite typically, the regulatory agency becomes a product of its environment, and forms an alliance with the regulated industry to prevent all change. Indeed, it is not too much of an exaggeration to state that becoming regulated by the government of the United States is something like losing a war to the United States: the government will look after your security forever.

On the other hand, it also must be acknowledged there are very serious problems involved in promoting competition which can generate a diversity of ideas, and provide the economy as a whole with a dynamic insurance policy, inasmuch as it is aimed at reducing the risks of pollution or inflation. One of these problems has to do with the formulation of criteria for judging acceptable performance. Under what circumstances should firms in an industry be dissolved, because instead of cooperating by competing they are cooperating by imposing risks on the public at large? To what extent should business firms be

allowed to make their lives more predictable, at the expense of making someone else's life less predictable? The other has to do with extending antitrust legislation to include constraints imposed by labor unions on productivity gains or on progress aimed at lowering the rate of environmental degradation.

The Criterion Problem: Concentration ratios have one principal advantage and one principal drawback as a criterion for determining the effectiveness of competition. The advantage is that they supply a fairly unambiguous criterion for antitrust action, which Blackstone lawyers (lawyers who go by the books) hopefully can carry out. The disadvantage is that market power is not likely to impose a reasonable test of competition as measured in terms of the degree of risk competitors impose upon each other. To be sure, there is a real danger that if an entire industry becomes dominated by a single firm, it will destroy the industry's ability to engage in unpredictable behavior. But short of dominance there is no magic number of firms which is required.

On the other hand, "the extent to which firms do or do not engage in consonant behavior" has one advantage and one disadvantage. The advantage of such a criterion is that it makes good sense. The disadvantage is that it does not lead to automatic rules for dissolving a business corporation for failure to engage in competition. If we knew beforehand just how large the technological potential was in the industry concerned, then, of course, there would be no problem in deciding whether there was sufficient cooperation in the industry to exploit the potential. However, since there is no way of measuring the potential, we can only infer whether there is a sufficient degree of cooperation, as measured, for example, by the ability of an industry to meet foreign competition. And the disadvantage of such an approach is that it stands as an open invitation to application of a "rule of season," and to nonenforcement of the antitrust laws.

So, what can be done about the apparent dilemma involved in providing reasonable criteria for antitrust enforcement? If we insist upon unambiguous rules which can be carried out by strict constitutionalists, we have no hope of coming up with rules which will make sense (that is, except in an imaginary unchanging world). On the other hand, if we insist upon sensible rules, then there is no assurance Blackstone lawyers can carry them out. This is a very thorny question; it will require a good deal of further work.

Regulation of the Labor Unions: These are the same kinds of thorny problems. For example, some constraints on productivity increases are for reasons of health and safety. But just where do you draw the line?

These are tough questions. All one can say is that if people refuse to grapple with them we will end up with an economy which features microstability and not macrostability.

FOOTNOTES

1. Robert M. Solow, "Technical Change and the Aggregate Production Function," Review of Economics and Statistics Vol. 39 (1957), p. 312.

2. Simon Kuznets, Economic Growth and Structure (New York: W. W. Norton & Co., 1965), p. 313.

3. Moses Abramovitz, "Resource and Output Trends," American Economic Review, Papers and Proceedings of the American Economic Association Vol. 46 (May 1956), pp. 5-23.

4. Raymond Vernon, "International Investment and International Trade in the Product Cycle," Quarterly Journal of Economics (May 1966).

5. Kuznets, Economic Growth and Structure, pp. 306-307.

6. Edward F. Denison, Why Growth Rates Differ (Washington, D. C.: Brookings Institution, 1967), pp. 305-308, 314-315.

7. Denison, Why Growth Rates Differ, p. 298.

8. William H. Gruber and Raymond Vernon, "The R&D Factor in the World Trade Matrix," in Technology and Competition in International Trade (National Bureau of Economic Research, October 1968).

9. Adam Smith, Wealth of Nations (New York: E. P. Dutton & Co., 1957), p. 128.

10. Alfred Marshall, Principles of Economics (Eighth Edition, London, Macmillan & Co., 1925), p. 32.

11. Burton H. Klein, Dynamic Economics (New York: Crane, Russak & Co., 1974).

12. John Maynard Keynes, The General Theory of Employment, Interest and Money (New York: Harcourt Brace Co., 1936), p. 245.

13. J. M. Keynes, Essays in Biography (New York: Macmillan and Co., 1933), p. 132:

The general idea, underlying the proposition of Value is determined at the equilibrium point of Demand and Supply was extended so as to discover a whole Copernical System, by which all the elements of the economic universe are kept in their places by mutual counterpoise and interaction.

14. Frank M. Knight, Risk, Uncertainty and Profit (New York: Houghton Mifflin Company, 1921), p. 19.

15. Frank M. Knight, "Diminishing Returns from Investment," Journal of Political Economy (March 1955), p. 52.

16. Klein, Dynamic Economics, chapter VIII.

17. Simon Kuznets, Modern Economic Growth: Findings and Reflections, Des Prix Nobel en 1971 (Nobel Foundation, 1972).

18. Leonard J. Savage, Foundations of Statistics (New York: John Wiley & Sons, 1962), p. 16.

19. Savage, Foundations of Statistics, pp. 46-50.

20. Richard P. Feynman, Robert B. Leighton and Matthew Sands, The Feynman Lectures on Physics (New York: Addison Wesley Publishing Co., 1966), pp. 1-2.

21. Smith, Wealth of Nations, p. 115.

22. Klein, Dynamic Economics, chapter 8.

23. Klein, Dynamic Economics, chapter 8.

24. C. D. Darlington, The Evolution of Man and Society (New York: Simon & Schuster, 1969), pp. 674-675.

25. Erich Fromm, The Anatomy of Human Destructiveness (New York: Holt, Reinhart & Winston, 1973), p. 370.

26. Donald W. MacKinnon, "The Characteristics of Creative Architects," (AIA_ACSA Teacher Seminar, 1963), and Edward B. Roberts, "Entrepreneurship of Technology," chapter 13 of Factors in the Transfer of Technology (Cambridge, Mass.: MIT Press, 1969).

27. Richard M. Cyert and J. G. March, A Behavioral Theory of the Firm (New York: Prentice Hall, 1963).

28. Tom Burns and G. M. Stalker, The Management of Innovation (New York: Tavistock Publications, 1961), p. 93.

29. Max Weber, The Theory of Social and Economic Organizations (New York: Oxford University Press, 1947).